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Volume 22 JANUARY, 1938 Number 1

BULLETIN
of the
American Association *of* Petroleum Geologists

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of the

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Volume 22 Number 1

BULLETIN
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PETROLEUM GEOLOGISTS

JANUARY, 1938

GEOLOGICAL HISTORY OF THE EAST INDIES[1]

J. H. F. UMBGROVE[2]
Delft, Holland

INTRODUCTION

In this paper it has been my aim to summarize, as objectively as possible, the facts known about the consecutive geological periods, in a series of sketches, reconstructing, so far as possible, the geological history of the East Indian Archipelago in the manner of the successive pictures of a cinematographic film. It is obvious that this film can not but be broken, and that many a picture will be vague. Also this summary may soon be out of date because the body of facts is growing continuously and rapidly. I often felt the lack of a summary of the historical development of this interesting island empire, from the Paleozoic to the Pleistocene, to be a great deficiency, during the time when I worked there myself. Consequently, I hope that the following summary may be of some use to many geologists. I tender my sincere thanks to Dr. R. D. Reed, chief geologist of The Texas Company (California), who persuaded me to publish a synopsis of this kind.

In the latest decades at least one or two hypotheses have been suggested every year to explain the structure of the East Indian Archipelago.[3] This shows not only that the exceptionally interesting

[1] Manuscript received, October 1, 1937.

[2] Professor of Geology and Paleontology.

[3] J. H. F. Umbgrove, "A Short Survey of Theories on the Origin of the East Indian Archipelago," Chapter VII in F. A. Vening Meinesz, *Gravity Expeditions at Sea*, Vol. II (1934). The more important theories are dealt with *in extenso* by Ph. H. Kuenen in: *The Snellius-Expedition*, Vol. V (1935), "Geological Results," Pt. 1.

territory of the Malay Archipelago commands the attention of many geologists, but also that many fundamental problems are unsolved.

It is not my intention to add another structural hypothesis to the respectable number already in existence. Considering the present state of science it seems more useful to outline sharply the gaps in our knowledge about the geological history of the archipelago. In the preface to their interesting paper on "The Structural Evolution of Southern California" (1936), R. D. Reed and J. S. Hollister write:

> We are not greatly attracted by the structural problems that seem fundamental to many geologists. The history of a structure interests us more than its mechanical cause.

This is an opinion with which I fully agree. Consequently I have made no attempt in this paper to explain the mechanical cause of the structurally different zones of the East Indies.

Concerning my preparation for this summary, I make the following statement.

In 1934 I published a paper on the Neogene, intended as a basis for comparison with the isostatic anomalies found by Vening Meinesz.[4]

At my instigation Badings made an investigation and tried to embody the history of the Paleogene in a series of paleogeographical maps.[5] After some geologists of the East Indies had criticized this first laudable attempt at constructing a paleogeography of the Tertiary, Badings was induced to embody in an erratum the points of substantial value made in their contentions.[6]

In the meantime I myself treated the pre-Tertiary history and displayed it on a series of maps in 1935.[7] The following account gives only a brief survey of the results obtained. I compiled the maps for the Neogene, which are published here for the first time, in 1936; Badings' maps date from 1935.

I have restricted myself to a minimum in mentioning facts and literature. After the appearance of Brouwer's *Geology of the Netherlands East Indies* (1925), the most important facts about the geology

[4] J. H. F. Umbgrove, "The Relation between Geology and Gravity Field in the East Indian Archipelago," Chapter VI in F. A. Vening Meinesz, *Gravity Expeditions at Sea*, Vol. II (1934).

[5] H. H. Badings, "Het Palaeogeen in den Indischen Archipel," *Verhandelingen Geologisch Mijnbouwkundig Genootschap voor Nederland en Koloniën*, Geol. Serie, XI (1936), pp. 233-99.

[6] *Ibid.*, XII (1937).

[7] J. H. F. Umbgrove, "De Pretertiaire Historie van den Indischen Archipel," *Leidsche Geologische Mededeelingen*, Vol. 7 (1935), pp. 119-55.

of the East Indies were summarized in an excellent book by Rutten.[8] This book furnishes us with a very reliable regional geological survey. By the same author an interesting review of geological research in the East Indies to the year 1923 was published in English.[9] Paleontological and stratigraphical data to the year 1930, as well as a synopsis of well known localities, have been published in a volume[10] in honor of the eightieth birthday of the Nestor of East Indian paleontology, Professor Dr. K. Martin.

All data about Malaya have been taken from Scrivenor's work: *The Geology of Malaya* (1931); those about Australia from: *Explanatory Notes to Accompany a New Geological Map of Australia* (1932) by the late Sir T. W. Etheridge David.

More recent literature may be found easily enough in the valuable bibliography of the publications on geology and mining for the East Indies and adjacent regions (*Geologisch Mijnbouwkundige Bibliographie van Nederlandsch Indië*) published by the Geological Mining Society for the Netherlands and Its Colonies (*Geologisch Mijnbouwkundig Genootschap voor Nederland en Koloniën*) and edited formerly by R. D. M. Verbeek, and since 1926 by N. Wing Easton.

The reader who is interested in the distribution of earthquake epicenters may be referred to the treatise by Visser,[11] while the most recent publication on deep-focus earthquakes is by Berlage.[12]

Figure 15 has been taken from a publication by Molengraaff.[13] Figure 19 is based on the catalogue of volcanoes by Stehn.[14]

I am much indebted to Ir. H. Terpstra, Dr. H. Schuppli, Dr. H. M. E. Schürmann, Prof. Dr. J. Wanner, Dr. Fr. Weber and Ir. A. van Weelden, who placed many data about different investigations at my disposal in advance of publication. Nobody is more conscious than I of the possibility that inaccuracies or mistakes may have

[8] L. M. R. Rutten, *Voordrachten over de Geologie van Nederlandsch Oost-Indië* (1927).

[9] L. M. R. Rutten, *Development of Geological Knowledge in the Dutch East Indies*, Koninklijke Akademie van Wetenschappen Amsterdam (1923).

[10] "Martin-Feestbundel," *Leidsche Geologische-Mededeelingen*, V (1931).

[11] S. W. Visser, "On the Distribution of Earthquakes in the Netherlands East Indian Archipelago," *Verhandel. Kon. Magnet. en Meteorol. Observatorium Batavia*, No. 22 (1930).

[12] H. P. Berlage, "A Provisional Catalogue of Deep Focus Earthquakes in the Netherlands East Indies 1918–1936," *Gerlands Beiträge zur Geophysik*, Vol. 50 (1937), pp. 7–17.

[13] G. A. F. Molengraaff, "On Recent Crustal Movements in the Island of Timor and Their Bearing on the Geological History of the East Indian Archipelago," *Proceedings Kon. Acad. Wetensch. Amsterdam*, Vol. XV (1912).

[14] *Netherlands Indies Volcanological Survey Bull.* 75 (1936).

crept into this paper. I have, however, willingly and gratefully made use of suggestions and criticisms concerning my earlier papers in so far as they have proved to be sound.

Figure 1 shows a comparison of coast lines and areas of the East Indies and the United States of America.[15] It is well to bear in mind continually that our enormous tropical island kingdom with its endless jungles, deeply weathered rocks and strong bottom relief offers grave difficulties for geological field work. This explains why, concerning many an island, our geological knowledge is very incomplete.

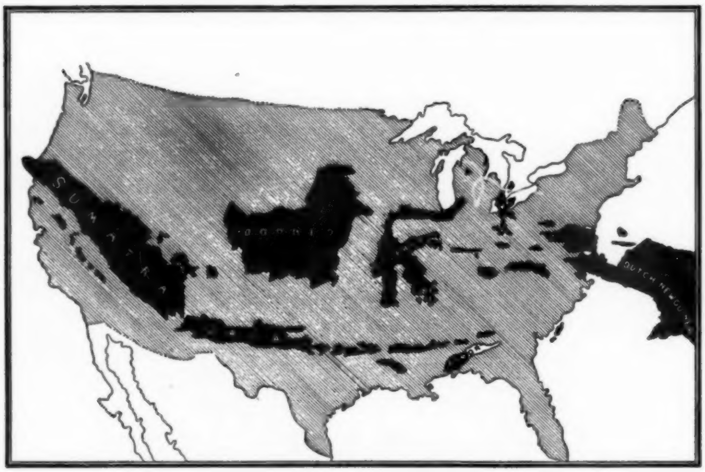


FIG. 1.—Comparison of coast lines and areas of the Netherlands East Indies and the United States of America.

Yet much and important work has been done in a comparatively short time, not the least of it by the members of the geological survey. Data have often been acquired with great mental and physical effort under difficult circumstances during expeditions through the jungle which command our respect.

If anything valuable is to be found in the following sketch of geological history, it must be remembered that this is only an attempt to reproduce something of decades of labor by a host of geologists who have devoted their best energies to science as well as to the economic development of the Dutch Empire.

[15] From *The Netherlands Indies*, published by the Division of Commerce, Department of Agriculture, Industry and Commerce at Buitenzorg, Java (1924).

On the maps and in the text the Dutch orthography has been used for geographical names ("oe" is to be read "u").

CHAPTER I. PALEOZOIC (FIG. 2)

It is with the Upper Paleozoic only that our knowledge of geologic history for the East Indian Archipelago begins. The age of the gneisses and crystalline schists is an open question for all the islands on which they occur. Nothing, however, testifies in favor of the Archean age that has been assumed for them by many former authors. Perhaps the Paleozoic, or part of it, is represented in schists and phyllites on some islands, as shown, for example, on the islands Letti and Sumatra. This remains a possibility for many areas. Part of the phyllites certainly belongs to the Mesozoic (Jurassic fossils on Borneo, New Guinea, and Sumatra). On the other hand, it is evident that in Central Borneo a part must be considered as belonging to the Eocene. Slightly phyllitic Eocene rocks have also been found on Celebes (Tinombo) and Halmaheira.

Strata of Cambrian age have not been found. There are formations of possible Silurian age along the river Lorentz in New Guinea, where *Halysites wallichii* has been reported. This occurrence is not certain, however, and this uncertainty is all the greater since other fossils from the same locality point to the Devonian. Several other localities on New Guinea are also regarded as Devonian. The distribution of Devonian, Carboniferous, and Permian is represented in Figure 2.

DISTRIBUTION AND FACIES

All marine fossils from the Paleozoic in the East Indian Archipelago come from neritic to littoral sediments. It is more than probable that islands or larger areas of land lay scattered about the Paleozoic shallow seas. This is indicated not only by the presence of Carboniferous plants, but also by the occurrence of weathering products of granitic rocks in Permian marine deposits in Western Sumatra (Padangsche Bovenlanden).

This fact alone proves the existence of granitic and porphyritic rocks of pre-Permian age; in addition, Dr. Musper demonstrated the probability of the existence of granite older than Lower Carboniferous, in the same region.

Permian volcanic rocks are known in Sumatra and Malaya as well as on the island of Timor. It may be accepted as a fact that many volcanic islands existed, but it is impossible to indicate the distribution of land and sea during the Paleozoic.

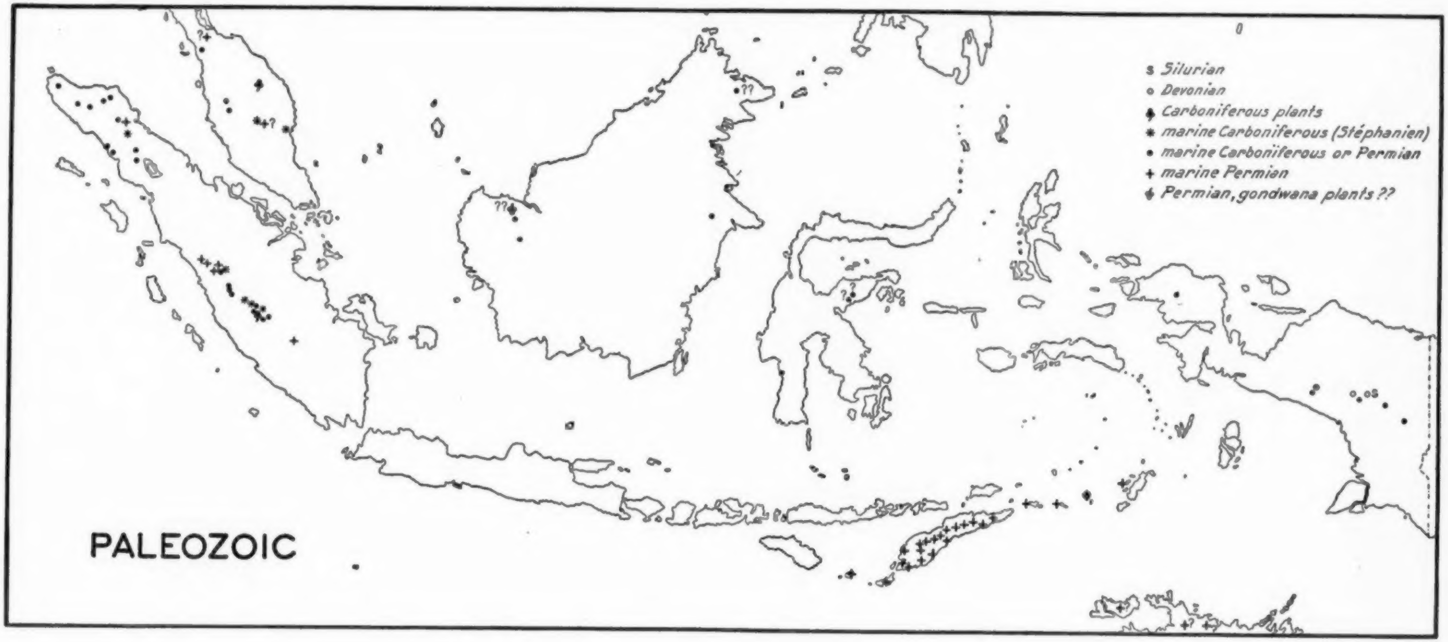

PALEOZOIC
s Silurian
o Devonian
Carboniferous plants
marine Carboniferous (Stéphanien)
marine Carboniferous or Permian
+ marine Permian
Permian, gondwana plants ??

FIG. 2

THICKNESS OF STRATA; PERMIAN-TRIASSIC CONFORMABLE SEQUENCES

On the island of Letti the Permian has a great thickness—at least 5,000 meters—as has been shown by the profiles given by Molengraaff; in central Sumatra a Carboniferous series of 1,750 meters was found.

In Central Sumatra the Permian merges gradually into Triassic sediments. Von Loczy (1934) suggests the same condition for the eastern arm of Celebes. On the basis of paleontologic data, the same may be considered probable for Timor. Musper expressly mentions it for Western Sumatra (Padangsche Bovenlanden). Scrivenor thinks he can assert it for Malaya.

UPPER PALEOZOIC FOLDING. PERMIAN-TRIASSIC UNCONFORMITY

An extensive series of volcanic rocks bearing the name of "Pahang volcanic series" is known in Malaya. It consists of volcanic ash, tuffs, lavas, quartz porphyries, granophyre, and fossilized mud-flow deposits.

As regards age, this series is considered to have begun, at the latest, in the late Carboniferous and to have lasted until the Triassic. Analogous rocks have been described from Western Borneo and the Riouw Archipelago. It has not been possible to ascertain the existence of an Upper Paleozoic unconformity in this area. According to Zwierzicky the Triassic near Prapat on Lake Toba (Sumatra) rests unconformably on phyllites, which he considers to be Upper Paleozoic. As this is the only angular unconformity of the sort that has been established with certainty in the entire western part of the archipelago, we shall—until this important question has been definitely settled by field research—have to consider two possibilities: either a local, more recently developed structural discordance, or a real unconformity caused by transgression. In the latter case we would meet with an Upper Paleozoic folding (and transgressive Triassic) in the area of Lake Toba. On the other supposition, we should have a conformable sequence from Paleozoic to Upper Triassic in Western Sumatra and Malaya.

An Upper Paleozoic folding has not been demonstrated with certainty in the eastern part of the archipelago either; there is a possibility, however, that the area of the Soela Islands, Obi and New Guinea, was folded towards the end of the Paleozoic. It is true that about the Soela Islands we know only that the Upper Lias rests, evidently unconformably, on ancient folded schists and phyllites of

unknown age, whereas the Triassic is absent, as it is on Obi; but analogous Jurassic rocks and fossils were found on New Guinea too. Here also the Triassic has not been found and here the Upper Paleozoic occurs also. These facts, taken together, seem to point to a movement after the Paleozoic, and before the Upper Lias—perhaps even before the Upper Triassic.

Chapter II. Mesozoic

Triassic (see fig. 3)

Western part of the archipelago

To get a good idea of the development of the Triassic in the western part of the East Indian Archipelago, the section that Musper (1929) studied in the uplands of Padang (Western Sumatra), north of Lake Singkarak, is of the greatest importance. Here he encountered a sequence which is briefly reproduced in Table I.

TABLE I

Triassic Sequence North of Mount Batoe Basi, Sumatra (Adapted after Musper)

Marly limestones with intercalations of clay shales (locally fossiliferous) and with a few layers of porphyritic tuff	±450 m	Triassic age proved by fossils
Porphyrite	± 2 m	
Marly shales, marly limestones and limestones	±100 m	
Marly shales and siliceous shales	± 60 m	Middle and Lower Triassic and transition beds from Permian to Triassic
Siliceous and marly shales with intercalations of radiolarites (containing well preserved *Radiolaria*)	± 60 m	
Permian strata		

I wish here to call attention to two points: (1) the conformity between Permian and Triassic; (2) the occurrence of *Radiolaria*-bearing rocks in beds representing either Lower Triassic or Lower Triassic and Upper Permian.

There is reason, moreover, to suppose that the Triassic developed in the same facies in other parts of Sumatra, Malaya, and Western Borneo.

In several places in Malaya Upper Triassic fossils have been found in shale, quartzite, and sandstone (*Myophoria*, *Halobia*). Furthermore, Scrivenor found (originally under the name of "Chert Series") several occurrences of "chert" and compact clay shales, both types with *Radiolaria*. Many people would perhaps be inclined to call these cherts radiolarites. Their age is considered to be Lower Triassic.

Now it is indeed striking that radiolarites also occur in Musper's

section below the Upper Triassic. The same sequence has also been found in Western Borneo. There, too, we meet with sandstones and clay shales in which, in Kendai and Serawak, *Monotis salinaria* and other Upper Triassic fossils were found.

In several places in the Sumatra Upper Triassic there have been found clay shales and sandstones with *Halobia* or *Monotis salinaria* which are considered to belong to Carnic, or perhaps Noric age.

In the Riouw Archipelago, also, the occurrence of marine Triassic is paleontologically demonstrated by the fact that a *Daonella* has been found, while the stem of a Mesozoic conifer (probably Triassic) from the Riouw Archipelago has been described.

In 1931 Scrivenor discussed at length his views regarding the origin of the *Radiolaria*-bearing Triassic rocks. He comes to the conclusion that these "cherts" can only have been formed in shallow sea-water, that is, in lagoons. *Radiolaria* were only locally enclosed in the siliceous "gel." He even thinks it not impossible that they have been formed locally in fresh water (where many remains of plants partly altered to peat have been found in the "gel"). Also in Western Borneo (Serawak) cherts with plant remains were found below shales of Noric age. This might also be explained, however, by supposing that the ancient marshes were flooded by the sea.

In any case we come to the conclusion that during Lower and Middle Triassic, in an extensive part of the Western Archipelago, circumstances were favorable to the origin of sediments highly charged with silica. For the rest, it is not quite clear what we must imagine these circumstances to have been.

Finally, we must mention here that there probably existed an extensive marine Triassic area in Borneo. The so-called Danau formation, which Molengraaff considers to be a typical Jurassic deep-sea deposit, might, according to other authors, belong to the Triassic. This formation is clearly older than the Lower Cretaceous, which locally rests unconformably on the intensely folded Danau formation; Hinde, moreover, on the strength of *Radiolaria* he examined, stamped the Danau formation as post-Paleozoic (possibly Jurassic). The distribution of this formation is indicated on the map (Fig. 3) of the Triassic. I shall again allude to this point at the end of the discussion of the Mesozoic. The appearance of the Danau formation in southwestern Celebes will also be discussed later on. Here I wish merely to mention my conclusion which will be developed in the following pages, that is, that the Danau radiolarites may prove to be the equivalents of the *Radiolaria*-bearing Lower and Middle Triassic sediments of Western Borneo, Malaya, and Sumatra.

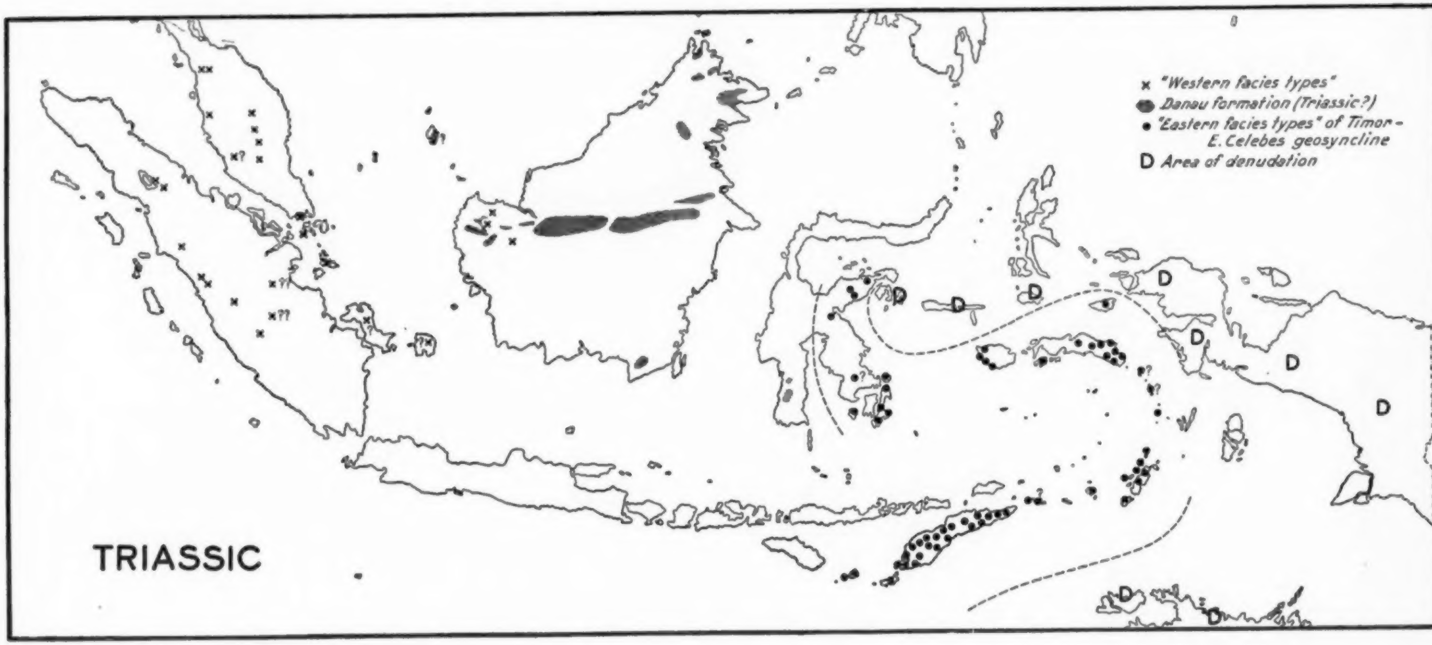

TRIASSIC
× "Western facies types"
Danau formation (Triassic?)
• "Eastern facies types" of Timor - E. Celebes geosyncline
D Area of denudation

FIG. 3

EASTERN PART OF THE ARCHIPELAGO[16]
THE COMPLICATED GEOSYNCLINE OF TIMOR-EAST CELEBES, BORDERED BY AN AREA OF DENUDATION

The most important data in the eastern part are known from two islands, Timor and Ceram, especially from Timor. The following five types of facies of the Triassic can be distinguished on Timor.

1. Scythic and Anisic are met with only in the form of Cephalopod limestones. We find this same facies in the Ladinic, Karnic, and Noric. It is remarkable that the entire Triassic occurs in Cephalopod facies. Perhaps we must suppose that the sedimentation was limited by submarine erosive action and sea currents. (Indeed, the whole of the Lower Triassic is only 2 meters thick!) This facies has been found only in the central zone of the island. According to Krumbeck's opinion these limestones were formed in the deeper parts of a neritic zone (analogous to the Hallstätter facies of Europe).

2. A second facies of the Triassic is the so-called Flysch facies (age from Ladinic to Noric): sandstones, "grauwackes," clay shales, sandy and slaty limestones. These deposits have great thickness. They were formed near the land, and in a neritic zone. In the Flysch there also occur many basic eruptive rocks; gabbro-peridotitic rocks as well as diabases, diabasic porphyrites, and melaphyres with their tuffs and tuff sandstones, on Timor, Tanimber, Ceram, Boeton, and in Eastern Celebes (Fr. Weber, 1935).

3. As the third facies we may mention brownish and reddish clay shales associated with radiolarian cherts, in some places with siliceous limestones containing *Daonella-Halobia* fauna (in the northwestern part of the island). Basic eruptive rocks occur associated with them. They are considered to be bathyal to abyssal.

4. The reef limestone facies occurs especially in the northwestern zone of the island. These rocks that strongly resist erosion in many places form prominent steep-sided outcrops in the landscape, called "klippen" or "fatus"; their age is Karnic and Noric.

5. Lastly, there occur bituminous marls and limestones. They contain oil near Lelogama and are considered to belong to the Rhaetic.

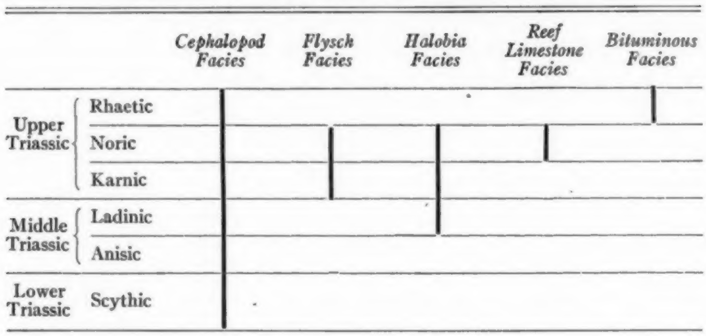
We may summarize this arrangement in Table II.

On Ceram only Upper Triassic rocks have been indicated by fossils; they occur in Eastern and Central Ceram in a Flysch facies containing oil. In Central Ceram it was possible to demonstrate a thickness of 800 meters. According to Rutten the Triassic in Western Ceram has a thickness of at least 1,000–2,000 meters.

[16] I may mention here that an interesting survey of the stratigraphy of the Mesozoic was given by Wanner in *Leidsche Geol. Mededeelingen*, Vol. V (1931).

TABLE II

DIFFERENT TYPES OF FACIES IN THE TRIASSIC OF TIMOR



On Boeroe, too, the Triassic (here also only Upper Triassic is known) consists of Flysch deposits, limestones, marly limestones, and asphalt slates. There is a great similarity to the conditions in Ceram, as is also the case with the Upper Triassic Flysch on the island Ambon. We find this Flysch also on the island of Boeton (also containing oil), where it has a Noric age.

On Celebes the Triassic is known from the eastern arm in the Tokala Mountains, and probably it has a great extent in the eastern part of Central Celebes.

More or less complete Triassic is known further from Portuguese Timor and from the islands Rendjoewa, Savoe, Rotti, Letti, Moa, Babbar, Tanimber, and Misool. Wanner's table of 1931 gives a clear summary of the facts mentioned.

If we summarize results for the eastern part of the archipelago, we may conclude as follows.

1. The different types of facies on Timor, Ceram, and Boeroe (especially on Timor) show that there were appreciable diversities in the depths of the neighboring seas during the Upper Triassic. During the Jurassic and Cretaceous we find indications of analogous conditions such as the Jurassic deep-sea deposits of Rotti and the Senonian of Timor.

2. A continuous sequence from Lower to Upper Triassic is known of one facies only, the Cephalopod facies (Hallstätter facies). For the rest, only the Upper Triassic is known from Timor as from all the other islands in the East. It is understandable that, on the basis of this condition, Wanner speaks of an Upper Triassic transgression coinciding with the origin of several diversified types of facies, that is to say, with the origin of deep-sea troughs and strong relief of the

bottom of the sea. As this applies to the islands of Savoe, Rotti, Letti, and Babbar, on which the Permian is known by the side of the Upper Triassic, a regression in those areas during Lower and Middle Triassic is suggested. Such a regression may, but need not, point to an orogenesis during those times, since it might also be explained by other causes. However, we must not forget that the conclusion regarding an absolute absence of marine Lower and Middle Triassic is based on negative evidence of a type that bids us be prudent.

3. There is a great resemblance between facies (especially Flysch rocks) in the occurrence of oil and asphalt, small layers of coal, basic eruptive rocks, and the fauna of the several localities in the eastern part. Wanner pointed this out more than once and Smit Sibinga devoted a special study to it. The deposits belong to a geosyncline wherein deposits accumulated from which the oil and asphalt found in the Moluccas may have originated (Fig. 3).

4. We can not escape the conclusion that, during the formation of the Upper Triassic deposits in the Moluccas, neighboring land was being denuded so as to supply the great amount of Flysch rocks deposited in the geosyncline. The material is in all probability derived from the eastern part of the archipelago. We shall again allude to this matter at the end of Chapter II.

To the eastern area of denudation belong: Northern Australia, New Guinea, Obi, the Soela Islands, and the Banggai Archipelago, on which no marine Triassic is known.

JURASSIC (FIG. 4)

WESTERN PART OF THE ARCHIPELAGO

In the western part of the archipelago only a few localities of Jurassic strata are known, for example, one in Sumatra and a few in Western Borneo. We know with certainty one locality of Jurassic strata only on Sumatra. Researches of specialists have shown that a fauna of mollusks which Tobler encountered in Djambi belongs undoubtedly to the Dogger. It occurs in strongly metamorphosed rocks with limestone lenses in the so-called "Bündnerschiefer facies." Concerning the very important question whether a conformable sequence from Triassic to Jurassic exists, or an unconformity, nothing can, unfortunately, be said with certainty.

In Western Borneo the Lower and Upper Lias have been pointed out, as well as the Malm.

EASTERN PART OF THE ARCHIPELAGO

1. *The Geosyncline of Timor-Eastern Celebes.*—We meet with an entirely different type of Jurassic sequence in the eastern part of the

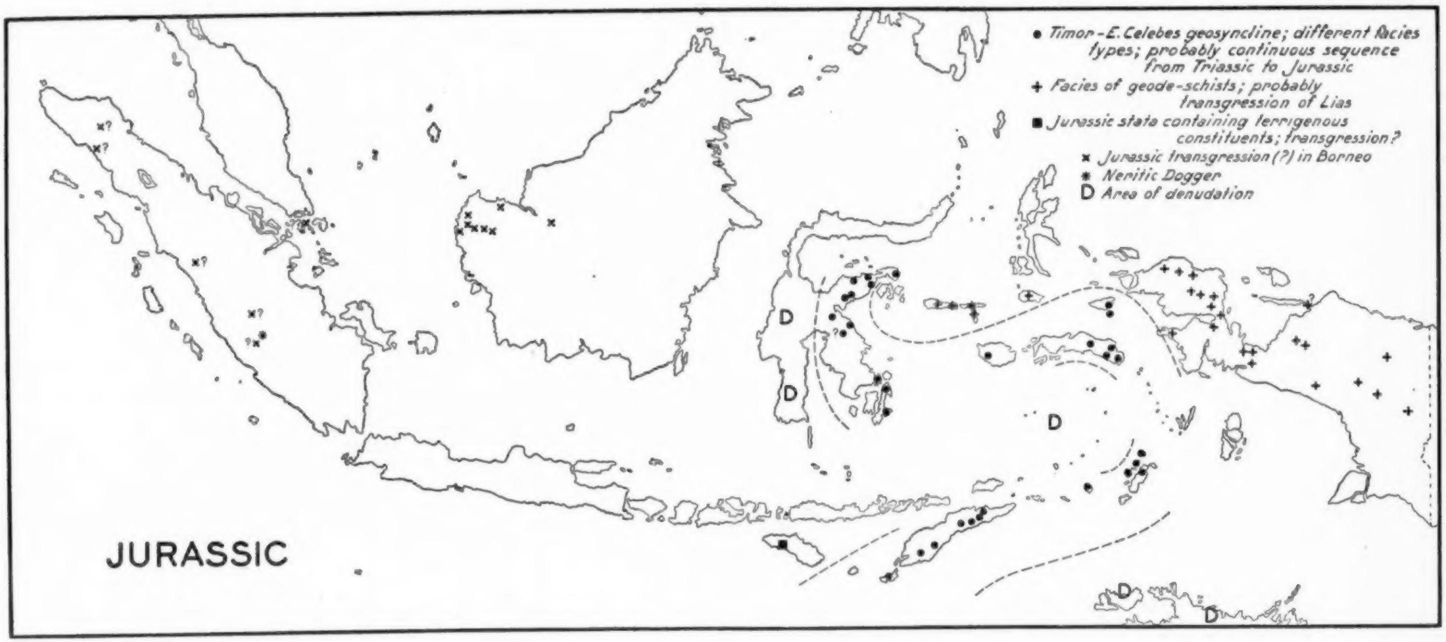

● Timor-E. Celebes geosyncline; different facies types; probably continuous sequence from Triassic to Jurassic
+ Facies of geode-schists; probably transgression of Lias
■ Jurassic slata containing terrigenous constituents; transgression?
× Jurassic transgression (?) in Borneo
✱ Neritic Dogger
D Area of denudation
D
JURASSIC

FIG. 4

TABLE III

DIAGRAMMATIC SUMMARY OF JURASSIC STRATA IN THE GEOSYNCLINE OF TIMOR-EAST CELEBES

				Rotti	*Timor*	*Babbar*	*Jam-dena*	*Ceram*	*Boeroe*	*Boeton*	*East Celebes*
Malm	Upper	Tithonian	Marly limestones; *Duvalia timorensis*	?	+		?	?	?	?	?
Malm	Middle	Kimmeridge	Cherty limestones (containing belemnites) and radiolitic cherts	+	+		o	+	+	?	?
Malm	Middle	Lusitanian									
Malm	Lower	Oxford	Limestones and marls; *Belemnites gerardi*	+	+		+			+	+
Malm	Lower	Oxford	Marly limestones; *Aucella, Inoceramus*	+	+		+	+	+		+
Dogger	Upper	Callovian	Ferruginous clays and marls; *Macrocephalites*	+	+	+ ?	+ ?	o ?			?
Dogger	Upper	Bathonian	Marls and marly limestones; *Prodicoelites*	+	+	+ ?	+	o			?
Dogger	Middle	Bajocian	Ferruginous clays; *Stephanoceras*	+	?	+ ?	+ ?	o ?			?
Dogger	Lower	Aalenian	Ferruginous clays; *Phylloceras nilsoni* var. *timorensis*	o	+	+ ?	+ ?	o ?			?
Lias			Different types of facies	X	X	X	X	X		X	X

o, developed in lithologically different rocks.

East Indian Archipelago, as is shown in Table III (according to Wanner, 1931, supplemented by data from Dr. Weber and Dr. von Loczy).

We shall not go into further particulars here. Suffice it to say that, as far as we know, no good sections exist in this area, and that our knowledge of the sequence was derived from fossils found and the study of samples of rocks. Thus where on certain islands stratigraphical gaps seem to occur, this may be the result of our as yet defective knowledge of these areas, and of insufficient exposures. That the apparent stratigraphic gaps are caused by gaps in our knowledge has been clearly shown by the ever increasing new data; at any rate in Timor two types of facies seem to be continued from the Triassic into the Lias, namely, the Cephalopod limestone facies and the reef limestone facies. It goes without saying, too, that very little is known about the thickness. It is probable that the Malm on Timor, for example, has great thickness, but no good sections are known. Rutten thinks it possible that, on Ceram, there is conformity between Triassic and Jurassic, but this has not been proved.

In opposition to Deninger, Wanner thinks that in Boeroe no complete Jurassic section occurs resting conformably on the Triassic, and that the Jurassic begins only with the Malm. It is a fact that no more is known about the Jurassic just there, but the possibility remains that, there, too, more may be found. According to von Loczy a conformable sequence was deposited during the Mesozoic in eastern Celebes.

Dr. Weber pointed out that the Lower Lias has not yet been found in the northern part of the Timor-East Celebes geosyncline. He supposes that in the zone of Boeton-(Boeroe)-Ceram-Misool the Middle Lias is probably transgressive on the Triassic.

2. *Soela Islands, Obi, New Guinea.*—Circumstances differ greatly on the Soela Islands, where not only do the Upper Lias deposits have the characteristics of a transgressive deposit (quartz sandstones and limy sandstones to conglomerates) but where possibly, or even probably, the area of these islands was land in the Triassic. In this region (Soela Islands, Obi, New Guinea), areas which, in their highly varied section of facies of the Jurassic, resemble each other, differ from the island belt discussed hitherto. No Triassic occurs on these islands. This is, admittedly, a negative characteristic, but it is nevertheless a remarkable fact that marine Paleozoic and Jurassic fossils have been found in many places, for example, in boulders of the Central Mountains of New Guinea, but not a single Triassic fossil has yet been seen. The similarity in the development of the Jurassic in these areas is summarized in Table IV (after Wanner, 1931). The Jurassic facies is

regarded as bathyal. From New Guinea only fragments such as boulders have been found and since these come partly from Tertiary conglomerates, nothing can be said about such matters as thickness. In all probability the Jurassic transgression had a very great extent in this area.

TABLE IV

JURASSIC STRATA ON THE SOELA ISLANDS, OBI AND NEW GUINEA

					Soela Islands	*Obi*	*New Guinea*
Malm	Upper	Tithonian			?		?
	Middle	Kimmeridge			?		?
		Lusitanian			?		?
	Lower	Oxford	*Belemnites gerardi* beds; *Inoceramus* beds	Clay-slates containing geodes	+		+
			Perisphinctes beds; *Peltoceras* beds		+		+
Dogger	Upper	Callovian	*Macrocephalites* beds		+	+	+
		Bathonian			?	?	?
	Middle	Bajocian	*Hammatoceras* beds; *Humphriesianus* beds		+	+	+
	Lower	Aalenian	Limy sandstones; *Hammatoceras* and *Belemnites exilis*		+		?
Lias		Different types of facies			+		+

Thus we find relatively close to each other different developments in the Jurassic: on the one side the area of the Timor-Eastern Celebes geosyncline, and on the other the area of the Soela Islands, Obi, and New Guinea; in the one area a probably conformable sequence at least since Upper Triassic, in the other an apparent Upper Lias transgression. Before that (during the Triassic) there was probably a large area of denudation here.

The question whether on the west side of the Timor-Eastern Celebes geosyncline there were any areas of denudation during the Triassic and Jurassic is closely connected with the problem of pre-Tertiary foldings and negative movements in those areas.

When this question is discussed later, we shall find that there are two possibilities. Folding followed by denudation, as in Western Celebes, either at the end of the Triassic or at the end of the Jurassic. In the former case, products of denudation could be furnished to the

area from Timor to Eastern Celebes during the Jurassic; in the latter case neither during the Triassic nor during the Jurassic.

In neither case is it probable that, during the Triassic denudation, products were supplied from the western part of the archipelago, to the Timor-East Celebes geosyncline. The Triassic Flysch of that geosyncline must come from the other side, that is from the area where now the Soela islands, Obi, New Guinea, and Australia are situated. Exactly along the edge of that area the Timor-East Celebes geosyncline originated not earlier than the Upper Triassic.

From the foregoing discussion, however, it follows that, during the Jurassic, when the area of the Soela Islands, Obi, and New Guinea was (at least for the greater part) flooded by the sea, extremely few, if any, denudation products can have been supplied from that side.

One possibility remains: that Northern Australia was, during the Jurassic, an area of denudation; marine Jurassic deposits are, in fact, not known and probably do not exist there. Now if folding took place in the western part of the archipelago towards the end of the Triassic, it is possible that much of the clastic material of the clays, marls, and marly limestones of the Timor-East Celebes area comes from this part. As long as the great gaps mentioned in the following pages remain in the pre-Tertiary history of these islands, it can not be established whether we may consider the western part—reaching from Malaya to Western Celebes—as extending to Sumatra, Java, and the lesser Soenda Islands, and the area lying between (Banda Sea).

Meanwhile the following information from Dr. Weber is of importance for this problem.

> On Tanimber and Ceram peculiar fine-grained sandstones, which are closely connected with radiolarian cherts, occupy a stratigraphical position that can not be quite explained in consequence of a lack of useful fossils. Lithologically there exists a great similarity to the quartz-sandstones of Misool of Lower Oxford age or older.
>
> The sandstone is very pure, contains no mica and very little clay. As the chief areas of distribution range 400–600 kilometers from north to south, the assumption of an Upper Jurassic mass of land lying between the two, as in the area of the present Banda Sea, would be consistent with the lithological similarity.

3. *Soemba.*—As long as so little is known about the pre-Tertiary history of the greater and lesser Soenda Islands, it is hardly possible to obtain a correct insight into the history of the remarkable island Soemba, about whose folded pre-Tertiary substratum very little can be mentioned. The clastic material of which the Jurassic rocks of Soemba consist (quartzitic sandstones with Upper Lias or Lower Dogger fossils) can, in any case, not have been brought from the

Rotti-Timor area, which, at the time, was submerged. So this material must have been supplied by a Jurassic area of denudation in the west or southwest, or perhaps from the north.

4. *Misool.*—On the north side of the Timor-Celebes zone and the "eastern" area lies the island Misool. It is remarkable that the development of the Jurassic on this island shows "affinities" with both zones mentioned.

In the lowest horizons there is a resemblance with the Soela islands; on the whole, however, there is more similarity to Ceram and Boeroe, especially in the Malm.

CRETACEOUS (FIG. 5)

EASTERN PART OF THE ARCHIPELAGO

1. *The geosyncline of Timor-East Celebes.*—The knowledge of a section of Misool that we owe to Dr. Fr. Weber is of the greatest importance to the stratigraphy of the Cretaceous in the East Indian Archipelago. Yet only the outline is known; details have not yet been published. The section is as follows.

TABLE V

CRETACEOUS SEQUENCE ON MISOOL (AFTER FR. WEBER)

Upper Cretaceous	Danian Maestrichtian Campanian Santonian Emscherian Turonian	Marls containing *Inoceramus* and rudistids (*Durania*); thickness 1,000 meters
	Cenomanian	Marly limestones, white and red fine-grained limestones and cherts containing *Globigerina cretacea*, *Gl. bulloides*, *Pseudotextularia globulosa*, and *Globotruncana canaliculata*
Lower Cretaceous	Albian Aptian Barremian	
	Hauterivian Valanginian	Limestones (without chert) containing *Hibolites subfusiformis*

This section is especially important for three reasons. 1. It proves that a conformable sequence is found from Jurassic to Upper Cretaceous; there are no unconformities. 2. The age of limestones with *Globotruncana* (*Discorbina*) *canaliculata*, *Globigerina cretacea*, *Globigerina bulloides*, *Pseudotextularia globulosa*, has, for a long time, been a much debated question. Now it appears, however, that they occur above the horizon with *Hibolites subfusiformis* (a Neocomian belemnite) and below the strata containing *Inoceramus* and rudistids, wherein Turonian and Senonian fossils were found. This microfauna resembles that of the Seewer beds in the Alps. Thus it belongs to the

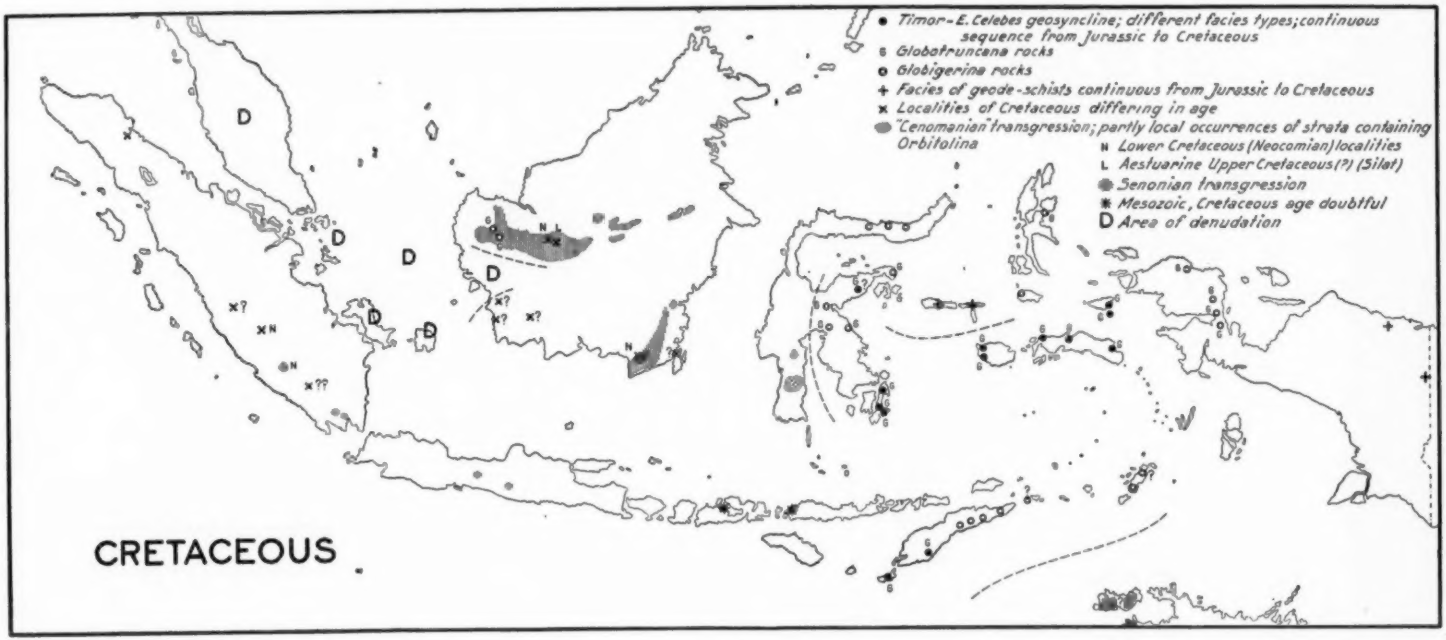

Timor-E. Celebes geosyncline; different facies types; continuous sequence from Jurassic to Cretaceous
Globotruncana rocks
Globigerina rocks
Facies of geode-schists continuous from Jurassic to Cretaceous
Localities of Cretaceous differing in age
"Cenomanian" transgression; partly local occurrences of strata containing Orbitolina
Lower Cretaceous (Neocomian) localities
Aestuarine Upper Cretaceous (?) (Silat)
Senonian transgression
Mesozoic, Cretaceous age doubtful
Area of denudation
CRETACEOUS

FIG. 5

lower part of the Upper Cretaceous (Cenomanian) and probably, in part, is older (Lower Cretaceous). 3. The *Inoceramus*-Rudistid marl is considered to be a shallow sea deposit, even merging into cross-bedded sand and delta deposits in the upper parts. This increasing shallowness of the sea is indicated also on other islands; on Rotti, for example, it is indicated by terrigenous material in the Upper Cretaceous foraminiferal limestones. Similarly, on Ceram and Boeroe, terrigenous material occurs rather commonly in the *Globigerina* marls.

We are justified in assuming that sedimentation was continuous from Jurassic to Lower and Upper Cretaceous, on Misool, Rotti, Timor, Ceram, Boeroe, and in Eastern Celebes.

Globotruncana rocks, as for the sake of brevity we shall call the fauna of small Cretaceous foraminifera, occur on Rotti, Timor, Ceram, Misool, Boeroe, Boeton, the eastern arm of Celebes; further, in the eastern part of Central Celebes, and its southeast arm. It also occurs outside this zone, namely, on Halmaheira, New Guinea (perhaps also on Obi), and in Western Borneo.

The *Globigerina* limestones of some islands are also considered to belong to the Cretaceous, although their age is doubtful and nothing whatever is known about their stratigraphical connection: examples on Letti (in Miocene breccias by Schubert), Tanimber Islands (by Brouwer), Obi and the Soela Islands (Brouwer), and the northern arm of Celebes (Schubert).

2. *The Soela Islands, Obi, New Guinea.*—On the Soela Islands as well as in New Guinea the facies of the geode schists was deposited uninterruptedly from Upper Jurassic time until Lower Cretaceous (Valanginian, Berriasian). In New Guinea they are known from the rivers Tawarin and Sepik (but only as samples from boulders).

Moreover some rocks from the neck of the so-called "Bird's Head" (New Guinea) have been described as containing the well known *Globotruncana* fauna.

WESTERN PART OF THE ARCHIPELAGO

A conformable sequence from Jurassic to Upper Cretaceous can be assumed with probability in only one area in the western part, namely, in schists of the Barisan Mountains in Djambi (Sumatra). Lower Valanginian has been described on the basis of a fairly rich marine shallow-water fauna. The locations of other, scattered, localities may be learned from Figure 4. They will not be discussed here any further; it may only be pointed out that *Orbitolina*-containing rocks are widely scattered throughout the western part of the East Indian Archipelago. These rocks point to an age from Middle Cre-

taceous to the lowest part of the Upper Cretaceous (Barremian-Cenomanian).

A rather extensive area in Western Borneo and Serawak is distinguished by *Orbitolina*-bearing rocks. A striking feature of this area is that the *Orbitolina* rocks rest unconformably on older sediments; that is to say, on the intensely folded Dañau formation, in places even with a clear basal conglomerate.

Moreover, it has been found in more than one place that the Tertiary rests discordantly on the Cretaceous. Thus we may assume one period of folding for post-Danau formation and pre-*Orbitolina* rocks; a second movement for post-*Orbitolina* rocks and pre-Tertiary. So, in Borneo, we can clearly establish the so-called Cenomanian transgression, "so-called" because we do not know for certain whether all *Orbitolina*-bearing sediments belong to the Cenomanian. It is possible that they comprise older *Orbitolina* rocks as well. This uncertainty does not greatly alter the conception, since in Europe, this world-wide transgression also began in the Lower Cretaceous and lasted into the Cenomanian.

In the East Indies indisputable indications of marine Lower Cretaceous, probably Urgonian, have been found in Southern Borneo near Martapoera. A series 1,000 meters thick, consisting of conglomerates and sandstones with a Lower Cretaceous *Nerinea*, rests unconformably on the Danau formation, while also in the Seberoeang region, an ammonite (*Hoplites neocomensis*) was found in the Lower Cretaceous. Perhaps we may regard the north of Australia as illustrating the Cenomanian transgression. David says about this (*op. cit.*, p. 85):

> Meanwhile, in late Albian time a small area was submerged near Darwin, and in Cenomanian time Melville Island was under the sea . . . .

The sediments of Melville Island are described as being:

> drab-coloured mudstone with *Inoceramus* cf. *etheridge;* and *Acanthoceras.*

Orbitolina is not mentioned. According to the section given by David this Cenomanian rests on the Paleozoic (Permian?).

SUMMARY OF MESOZOIC HISTORY (SEE FIGURE 6 AND TABLE VI)

On many islands there exists an unconformity between the Eocene and the pre-Tertiary. This supplies an indication of pre-Eocene movements. As, however, in some areas very intensive Tertiary foldings have taken place as well, which have, as it were, kneaded Tertiary and pre-Tertiary into a chaotic structure, the pre-Tertiary

movement can, in many places, only be inferred from the occurrence of pre-Tertiary rocks in Eocene basal conglomerates.

A. Thus we may assume a late Cretaceous folding (after Senonian and before Tertiary *a*) in the Timor-Eastern Celebes zone, where, for the rest, conformable sequence occurs at least from Upper Triassic to Upper Cretaceous, probably since the Permian, in part of that zone at least. Weber thinks that, in the eastern part of Celebes, we must take into account a regression in the Lower Lias. We must, however, remember that, during the Mesozoic, this area was characterized by strong relief (neritic as well as bathyal and abyssal deposits of the same age have been met with), so that a trough with conformable sequence may be found at a short distance from an area with regressions and transgressions. Basic eruptive products are widely scattered throughout the Timor-Eastern Celebes belt on Timor, Tanimber, Ceram, Boeton, and in Eastern Celebes. They belong, in all probability and certainly for the greater part, to the Triassic (Fr. Weber, 1935). The opinion of von Loczy (1934) that the ultra-basic eruptive rocks of Eastern Celebes would prove to belong to the Upper Cretaceous is, according to Fr. Weber (1935) and W. H. Hetzel (1935), disproved by the occurrence of boulders of ultra-basic rocks in sediments of Upper Mesozoic, probably Jurassic age.

This zone formed an area that has a history different from that of the surrounding areas. Considering the great thickness of the Paleozoic on the island Letti, it seems not improbable that the forming of this remarkable geosyncline took place in the Permian.

B. It is possible to define the boundaries of the zone mentioned under *A*, though only in part and schematically, because we know something, although very little, about the surrounding areas, where the Mesozoic history is entirely different. Thus, for example, from the Soela Islands, Obi, New Guinea, and Northern Australia, which, in all probability, formed an area of denudation during the Triassic, and which were submerged by the Jurassic sea, we are justified in supposing that a late-Paleozoic movement took place in these areas.

For the rest, it seems that the Mesozoic of the Soela Islands and Obi is clearly but weakly folded. It is impossible to fix the time of that movement. It is not impossible that the late Mesozoic or the more intense Tertiary movements in both of the areas mentioned under *A* have made themselves felt, though in a modified degree, in this area, which is, as it were, situated between the two. Perhaps the Banggai Archipelago belongs to that area as well. On the other hand, the more recent, and especially the Tertiary history of the Central Mountains on New Guinea is much more complicated. This area may

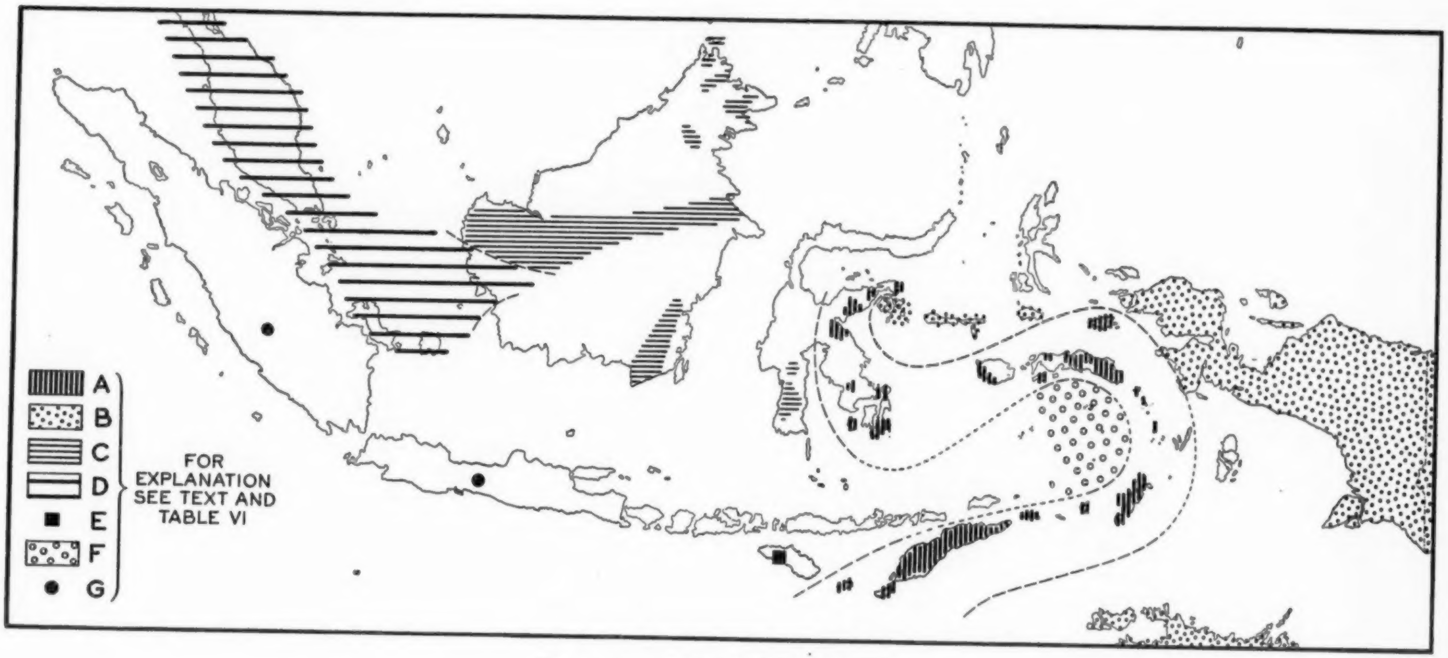
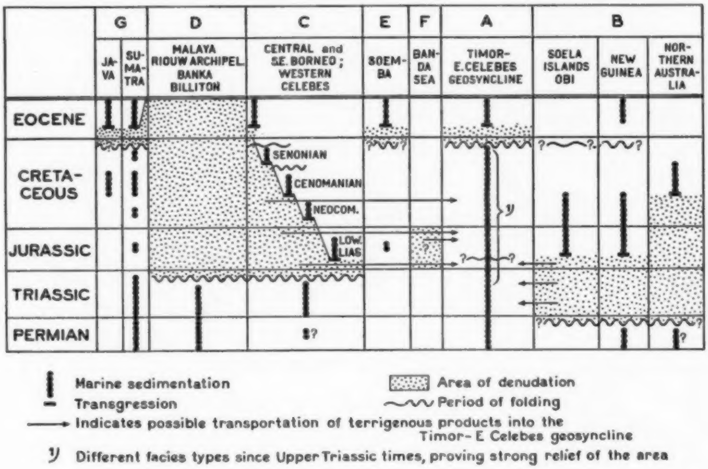


FIG. 6.—Areas differing in Mesozoic history.

TABLE VI

SUMMARY OF MESOZOIC HISTORY. (COMPARE FIG. 6.)



have become a geosyncline again since the Jurassic, and perhaps folding occurred in the Cretaceous. Our knowledge of New Guinea is, however, too slight to enable us to say anything about this with any certainty.

In the discussion of the Triassic it appeared that we must regard the zone mentioned under *A* as a geosyncline that was supplied with material coming from a vast area of denudation which comprised at least Northern Australia, New Guinea, Obi, and the Soela Islands, and probably also the Banggai Archipelago. This, as well as the results obtained concerning Jurassic and Cretaceous, is incompatible with the line of thought about the origin of the East Indian Archipelago given originally by Wegener and worked out by other authors.

C. The history of Western and Central Borneo is entirely different. It is there that we find the Danau formation which was intensively folded and denuded, certainly before the Lower Cretaceous and perhaps towards the end of the Triassic (see under *E*). This formation is unconformably covered probably by Jurassic rocks, certainly by Lower Cretaceous and the "Cenomanian" transgression. These sediments are, in their turn, folded and unconformably covered by Upper Cretaceous (Silat), while ultimately a weak pre-Eocene movement took place (see further under *E*). It is probable that this statement, with the necessary changes, may also be applied to Southeastern

Borneo and probably also to Celebes (Central and Southern Celebes).

The Lower Lias transgression in Western Borneo is indicated on Table VI as well as the Lower Cretaceous on Borneo and Sumatra, the Cenomanian transgression and the Senonian transgression on Southeastern Borneo near Martapoera.

D. Probably about simultaneous with, or shortly after, the intensive folding of the Danau formation, numerous granite batholiths developed in Southwestern and Central Borneo. It seems that the many granite batholiths of Malaya, Billiton, and Banka are post-Triassic too. The area, roughly indicated in this way, was probably not influenced by the Cenomanian transgression. It had been gradually lifted above sea-level after the Triassic, but not without the Triassic and the Paleozoic having been intensively folded. The time of the folding of this area is towards the end of the Triassic, and perhaps we are justified in correlating it with the intense folding of the Danau formation (Early Cimmerian phase according to Stille's system). This question depends immediately on the query: how old is the Danau formation? If it belongs to the Jurassic, we get the following picture: an intensive folding on Malaya, Banka, Billiton and Western Borneo, towards the end of the Triassic, and, surrounding this area, a zone, partly bounding it immediately, where the Danau formation has been intensively folded towards the end of the Jurassic. If, on the other hand, the Danau formation belongs to the Triassic, then a simultaneous period of folding may be supposed for both areas. The wide limits between which the age of the Danau formation may range, according to paleontological data (post-Paleozoic and pre-Cretaceous), admit of the second possibility. Presupposing the same period of folding in Upper Triassic or Lower Jurassic for a Triassic Danau formation as well as for the area from Malaya to Banka and western Central Borneo, the scattered localities of neritic Jurassic in Western Borneo must be regarded as transgressive deposits, as, indeed, they appear to be.

As explained before, only a movement towards the end of the Triassic would produce an area of denudation from which the terrigenous material of the Jurassic sediments in the eastern part of the archipelago (zone *A*) might, for the greater part, come.

In Table VI and on the maps this opinion is expressed because it seems to be the most probable.

We now revert to the discussion of the facies of the Danau formation. Scrivenor regards the Lower Triassic "radiolarites" of Malaya as shallow-water deposits. Triassic radiolarites in Western Borneo lead us to the same conclusion. On the other hand we have Molen-

graaff's opinion that the radiolarites of the Danau formation, which, in my opinion too, belong to the Lower Triassic, are typical deep-sea sediments.

There are three possibilities: either Scrivenor is right, or Molengraaff, or both in so far as perhaps local neritic organisms or even material from the land have been fossilized in radiolaritic rocks, while in general the deep-sea genesis holds good for real radiolarites. There is no use in trying to choose between these three possibilities. The problem can only be solved by a great number of new data obtained by field observations and petrographic examination of sediments.

E. Part of the zone mentioned under *A* was bounded on the northwest by an area of which very little is known, namely, Soemba. In Soemba Eocene rests unconformably on folded pre-Tertiary. The period of folding can not be fixed more accurately than post-Jurassic and pre-Eocene.

In the Jurassic Soemba shows a resemblance to the area of the Soela Islands, as regards the character of the sediments.

The clastic material in the Jurassic rocks of Soemba suggests an area of denudation which may have been situated either west or northwest of Soemba, or perhaps north. It can not have come from an area on the southeast because that area was, at the time, below sea-level.

F. Very little can be said concerning an area like the Banda Sea. Weber pointed out that the character of sediments, probably belonging to the Jurassic, on Ceram and the Tanimber Islands, indicates the existence of land (denudation) in the area of the present Banda Sea. Meanwhile, this demonstrates in the clearest way the importance of sediment-petrographic data for such problems. An increase of our very elementary knowledge of the pre-Tertiary history of the greater and lesser Soenda Islands will be of the greatest importance for obtaining an insight into the Mesozoic history of the Banda Sea.

G. The picture given can not but be incomplete as long as so few details are known about many pre-Tertiary areas. A striking example in this regard is Sumatra. Did continual sedimentation from Permian or Carboniferous to Upper Cretaceous take place on this island or in part of it? Are we to take into account only one pre-Upper Cretaceous period of folding during the Mesozoic? Even regarding these fundamental questions we have no certainty. The Carboniferous, Permian, and Triassic are quite well known locally. Of the Jurassic only one remarkable Dogger fauna is known with certainty. Our knowledge of the Cretaceous leaves much to be desired. Only very recently it became evident that the supposed Triassic of the Goemai Mountains

belonged to the Cretaceous, probably the Lower Cretaceous. Detailed stratigraphical surveys are still to be made in many places.

We may summarize as follows. Many authors think it probable that continual sedimentation took place during the Mesozoic in the area of the so-called "Bündnerschiefer" (where, however, only Dogger has been indicated with certainty) and that a period of folding occurred towards the end of the Cretaceous while in the Lower Cretaceous there may have been a movement which might be suggested by a bed of conglomerates in the Lower Cretaceous of Djambi.

Little is known about the pre-Tertiary history of Java. In his latest publication (1933) Harloff suggests that probably the largest of three Javanese pre-Tertiary areas, the Loh-Oelo Mountains, belong to a zone of Upper Cretaceous folding, that is to say, of folding after the deposition of the *Orbitolina*-bearing limestones (the only pre-Tertiary rocks on Java of which the age is approximately known).

Some time ago (1929) the same author argued that, although no unconformity is known below the Cretaceous series, its existence can not be doubted:

> One need only observe the great difference between the highly metamorphosed micaceous rocks with their lenticular inclusions of marble and the much less altered sediments with their marly limestones in the Lower Cretaceous to be confirmed in his opinion that the latter were deposited on the former after a considerable period of denudation.

He believes the older series to be Lower Mesozoic, Triassic, or Jurassic. Does a "Cenomanian" transgression occur on Java? Perhaps also on Sumatra? Is the pre-Tertiary history of Java (and the other Soenda Islands) connected, in its essentials, with that of Borneo and the western part of Celebes? The results mentioned here seem to point in this direction, but until more data are available it is better to refrain from suppositions. In any case it seems probable that the folding towards the end of the Mesozoic was much more intensive on Sumatra and Java than it was on Borneo.

Chapter III. Cenozoic

TERTIARY

INTRODUCTION. STRATIGRAPHY. GENERAL REMARKS

The synopsis of the Tertiary history has been kept as concise as possible. Undoubtedly there is a drawback in the fact that the reader is confronted with only a short summary and not with a complete detailed and critical discussion. This meagerness is also applicable to the previous chapters about the pre-Tertiary. If, however, we were

to search into the actual bases of the opinions given here, the inevitable result would be that this article would grow into a bulky volume. Moreover, this would increase the chance of the reader not being able to see the wood for the trees.

Those who may find my summary an incentive to further study of the subject, I refer to the publications mentioned in the beginning of this article, which may serve as a key to an extensive literature.

When the comprehensive and very exact studies of K. Martin on the Tertiary of the East Indies had proved, among other things, that in the Miocene and younger faunas of this area no European species occur, the correlation of the Neogene strata of this autochthonous East Indian area became a separate and difficult problem in itself. A correct correlation of the East Indies and Europe, especially of the subdivisions of the Tertiary, is not yet possible. For this reason Dr. I. M. Van der Vlerk has introduced a "letter classification" of the East Indian Tertiary, based on the foraminifera.

This classification, which has been generally accepted, has many advantages. It avoids the use of names the meaning and range of which are not fully grasped. Later on, when it has become possible to make exact correlation, the student will be enabled to understand, at once, the older literature in which these faunistic symbols have been used, which with the use of names like "Aquitanian" and "Burdigalian" is far from being the fact.

A more elaborate classification according to this principle was worked out by Leupold and Van der Vlerk. This is shown in Table VII.

In the following pages "Lower Miocene" stands for Tertiary *e* and "Upper Miocene" indicates the Miocene strata younger than Tertiary *e*.

I must emphatically point out that the paleogeographic maps, although they have been composed as objectively as possible, give diagrammatic pictures only. Moreover, several uncertainties undoubtedly have remained in them, inherent in the character of the data. Let me give one example of the uncertainty of the notation "probably land." On the Soela Islands the excursions that were made only revealed pre-Tertiary rocks *in situ*. The possibility that one part was temporarily covered by marine Miocene, for example, remains open; in this special case the fact that some loose limestone boulders with orbitoids have been found, might point to this.

In a comparative study the paleogeographic maps should be used with a grain of salt. But on the other hand these remarks need not give rise to a spirit of captious criticism for, if the maps given and the

following description represent nothing but a sketch, there are yet remarkable facts that are of importance. Besides the maps a series of sections (Plate 1) is given, taken from the following publications.

Section 1. G. A. F. Molengraaff, "Folded Mountain Chains, Overthrust Sheets, and Block-Faulted Mountains in the East Indian Archipelago," *Compte-Rendu XIIth Congres Geol. Intern.*, Toronto (1913), Pub. II, Section I.

Section 2. W. C. B. Koolhoven, "Verslag over een Verkenningstocht in den oostarm van Celebes en den Banggai-Archipel," *Jaarb. Mijnw. Nederl. Indië* (1929), Verh., Section H. L.

Section 3. A. Tobler, "Djambi-verslag," *Jaarb. Mijnw.* (1919), Verh. 3, Bijlage 5, Section 9.

Section 4. H. Jetzler, "Das Ölfeld Sanga-Sanga in Koetei," *Zeitschrift für praktische Geologie* (1926), Taf. I, Fig. 2.

Section 5. A. Ch. D. Bothé, "Djiwo-Hills and Southern Range," *Fourth Pacific Science Congress (Java, 1929) Excursion Guide C 1*, Section A-B.

Section 6. J. Zwierzycki, "Geologische overzichtskaart van den Nederlandsch-Indischen Archipel 1:1,000,000 Blad XIII," *Jaarb. Mijnw. (1930)* Verh. 3, part of Section A.B.

Section 7. J. Westerveld, *Geologische kaart van Sumatra 1:200,000* (1933), Blad 3, Section C.D.

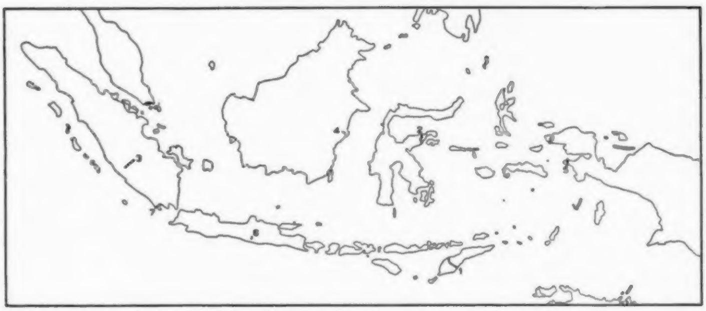


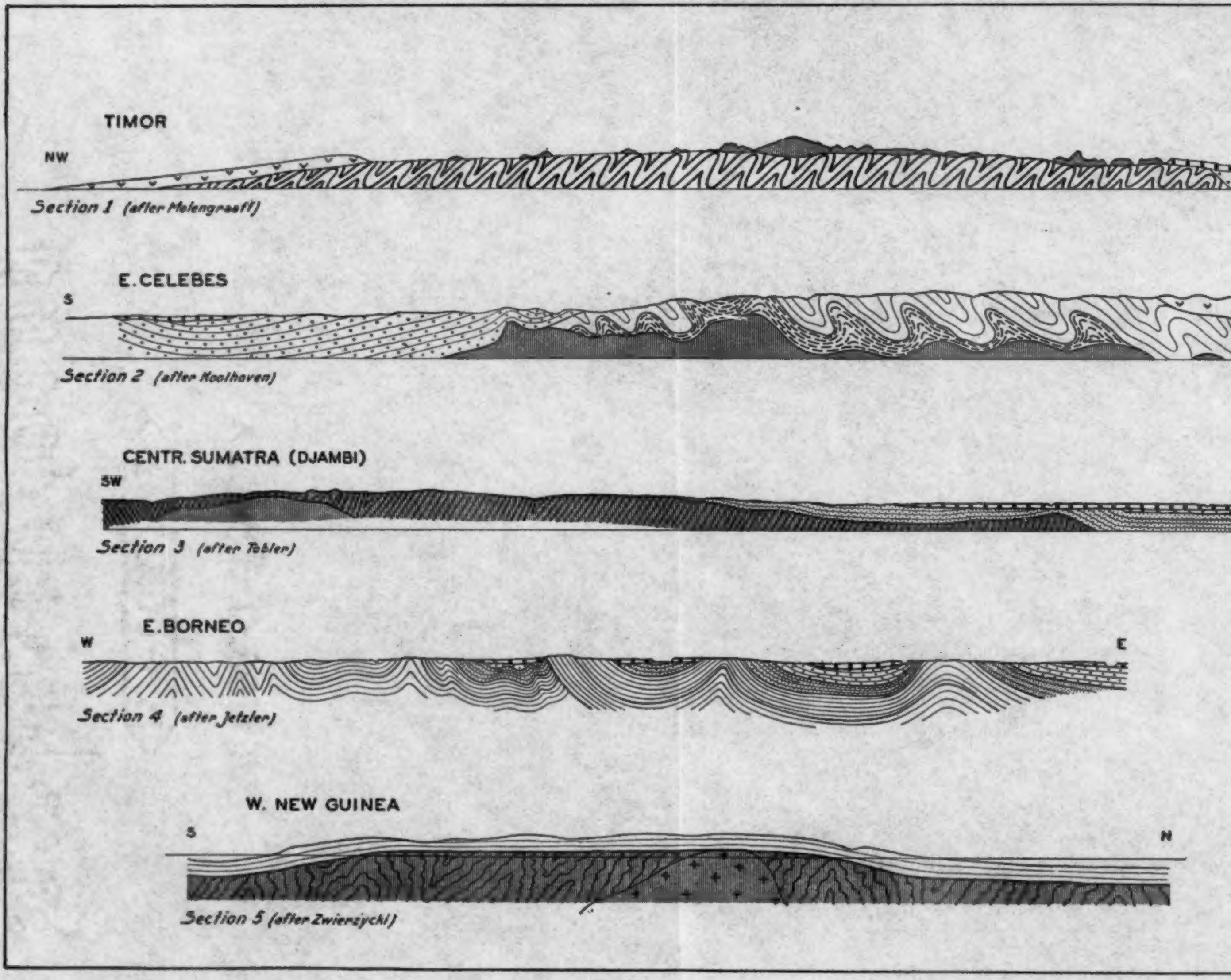
FIG. 7.—Location of Sections 1–7.

The location of the sections is indicated on Figure 7. These sections are drawn on the same scale, that is, on the same horizontal and vertical scale. To render mutual comparison easier, I have introduced similar indications for Pleistocene, Pliocene, Miocene, *et cetera*. The following particulars are important.

Section 1.—Since Molengraaff published this section it has been proved that Lower Miocene occurs in the "pre-Tertiary" and "Paleogene" with chaotic structure.

Section 4.—The stratigraphic interpretation of Jetzler's section has been given according to Leupold and Van der Vlerk (1931 Table).

Section 7.—The diagonal striping relates for the greater part to andesitic products in which marine intercalations of the Lower Miocene occur.


TIMOR
NW
Section 1 (after Molengraaff)
E. CELEBES
S
Section 2 (after Koolhoven)
CENTR. SUMATRA (DJAMBI)
SW
Section 3 (after Tobler)
E. BORNEO
W
E
Section 4 (after Jetzler)
W. NEW GUINEA
S
N
Section 5 (after Zwierzycki)

LATE I. "GEOLOGICAL HISTORY OF THE EAST INDIES," BY J. H. F. UMBGROVE

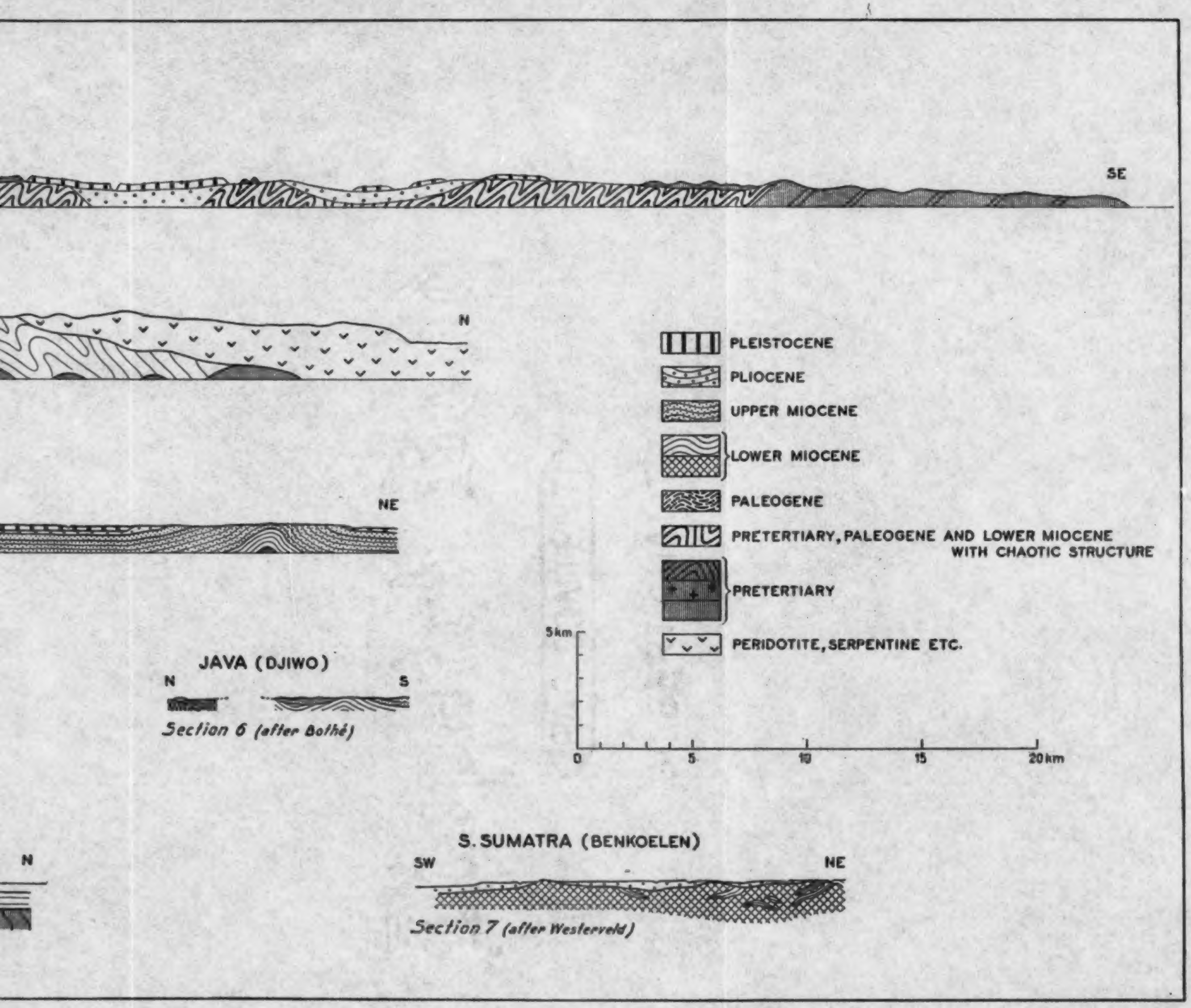


Table VII gives a diagrammatic view of the stratigraphy of some areas. An analogous table was published by me earlier (1934) but it is here brought up to date on the basis of later publications of several authors.

PALEOGENE DEPOSITS; PALEOGEOGRAPHY

Figure 9 gives a concise picture of the entire Eocene. All marine deposits originate in shallow transgressive seas of which the unconformity, on pre-Tertiary rocks, has for the greater part either been proved or strongly suggested by the occurrence of fragments of pre-Tertiary rocks in those marine Tertiary sediments; from which it follows that those areas must have been land before that time. The data supplemented by analogous deductions for areas where no marine Eocene and in part of which no marine Paleogene occurs, but where one or more horizons of the Neogene rest unconformably on the pre-Tertiary, suggest that the area of the East Indian Archipelago may for the greater part have been occupied by an extensive land area towards the end of the Mesozoic and the beginning of the Eocene. This is clearly illustrated by Figure 8, compiled by Badings.

It is true that there is much virgin territory and there is much that could only be marked as "supposed" or "probable," but on the other hand, we have three general facts tending to support the suggestion of the map: (1) it could not be proved with any certainty that marine conformable sequence occurs anywhere in the archipelago from pre-Tertiary to Eocene, while the possibility of such conformable sequence is left open for two places only (Western Celebes and a part of Tanimber); (2) the clearly increasing extent of the several Paleogene and Neogene transgressions; (3) the pre-Tertiary history of the archipelago which (as far as is known) leads to the same conclusion, namely, the presence of extensive areas of land toward the end of the Mesozoic (see Figure 6 and Table VI).

If, with Arldt,[17] one supposes that the ancestors of the Monotremes reached Australia from India during the Jurassic, one is obliged to suppose a land bridge to have existed which must have been situated south of the present archipelago.

The transgression of the Eocene is indicated on Figure 9. Although I have intentionally avoided uniting the scattered occurrences of marine Eocene in an Eocene sea of hypothetical extent, it is evident, from the similarity of the marine faunas that are repeatedly met with, that these areas must, in one way or another, have been connected. A glance at the map shows that it is only locally possible to determine

[17] Th. Arldt, *Die Entwicklung der Kontinenten und ihrer Lebewelt,* I (1936), pp. 35, 36.

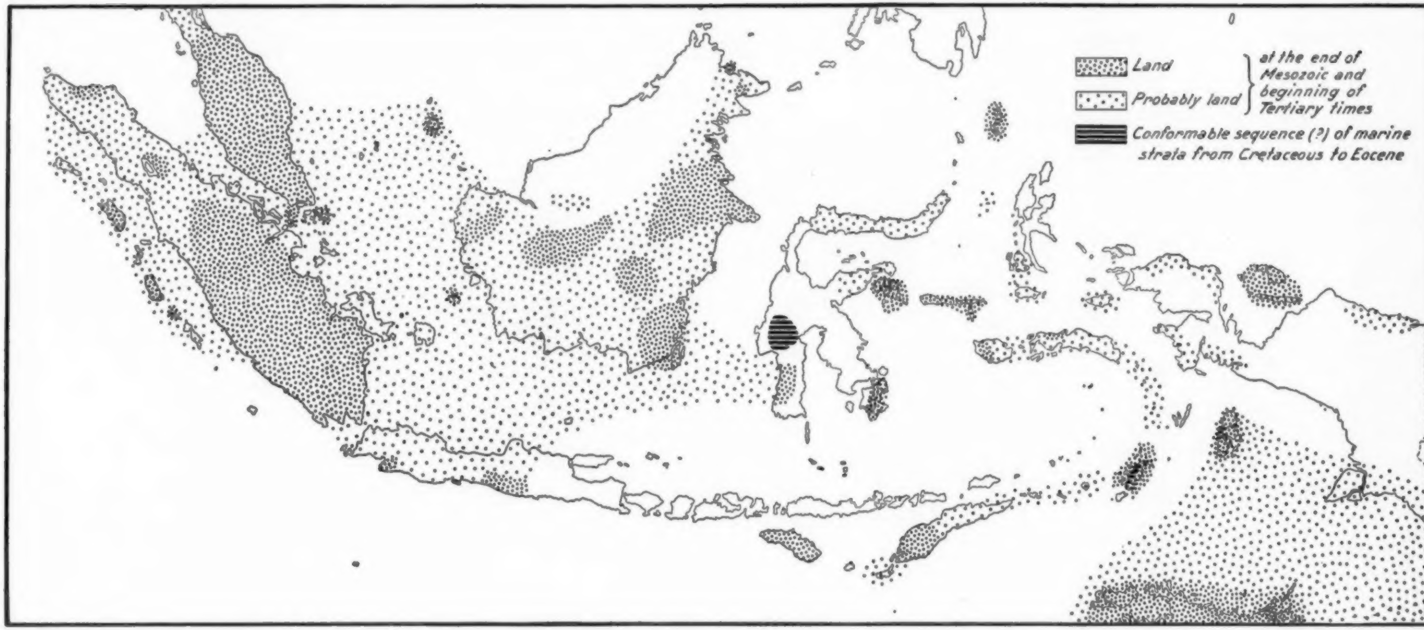


FIG. 8.—(Adapted from Badings.)

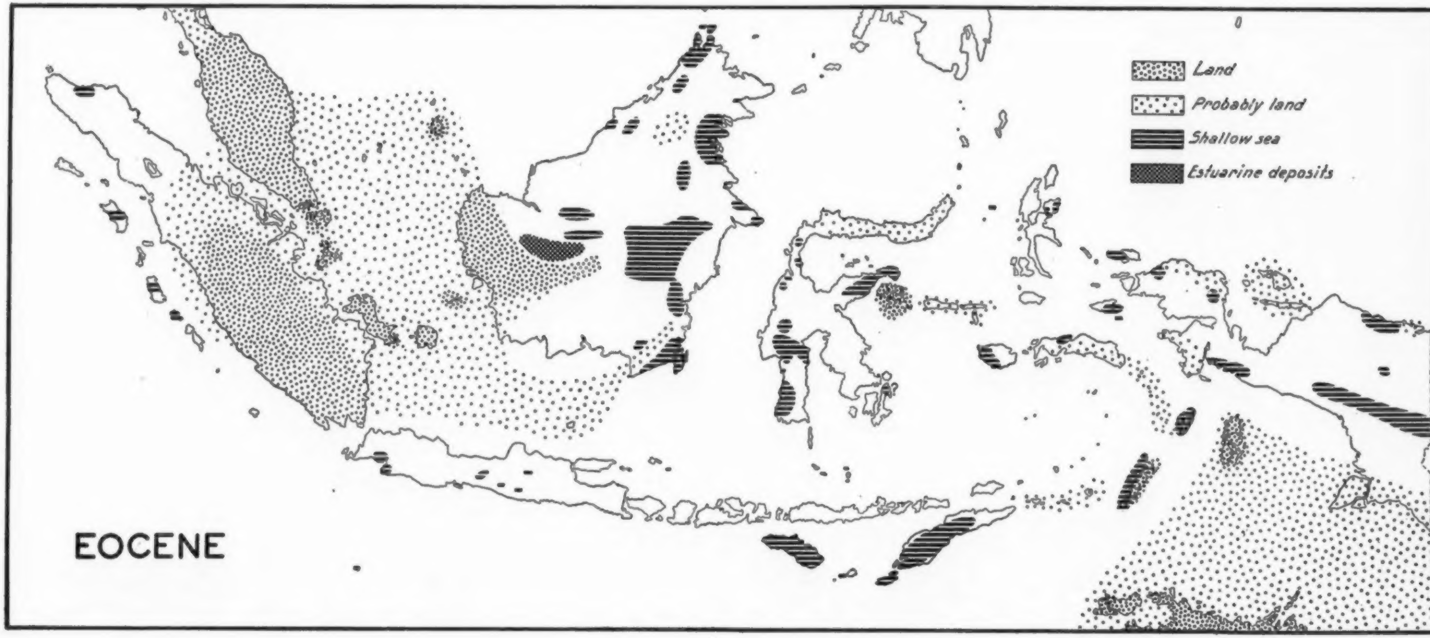


FIG. 9

the boundaries between land and sea at that time, but at the same time it is evident that the data tally with the opinion that a transgressive sea separated an Asiatic land area from an Australian.

It is hard to express, in European stratigraphic terminology, the time when the oldest Tertiary transgression began. The oldest Eocene marine deposits of the archipelago may be those of the Soengei Taballar (East Borneo) and they may perhaps be correlated, as regards age, with the European Montian.

It is important to mention that all marine Paleogene sediments we know in the East Indian Archipelago have been deposited in shallow epicontinental seas (neritic and littoral). The strong relief, as we know it at this moment—the many deep-sea basins—originated much later, as will be explained.

Anticipating these explanations, I think I can best characterize the history of the East Indian Archipelago in the words of Chubb. " . . . an area of continental land that was gradually folded, fractured and submerged in Mesozoic and Tertiary times." Chubb's formulation was intended to apply to Melanesia. Not only do the Dutch East Indies show many points of similarity with Melanesia, as I pointed out elsewhere,[18] but they are connected with it and form a physiographic and geological whole. We shall quote Leuchs' similar opinion farther on. For a detailed study of the paleogeography of the Lower Tertiary I must refer to the original discussion by Badings.

Figure 9 is only a diagram wherein all marine Eocene localities are summarized. Thus it gives a maximum of marine Eocene notations.

PALEOGENE MOVEMENTS

The gaps in our knowledge of the Paleogene history become very evident when we try to obtain an insight into the orogenic and epeirogenic movements which took place during that time, to say nothing about the distribution of volcanism. On the stratigraphic table which I published in 1934 and which is again given here (Table VII), brought up to date with the newest data that have appeared since then, the gaps beneath Tertiary *e* 5 are already striking on many islands.

The curved line drawn in Tertiary *e* 4 has only two fixed points (Tanimber and Bantam). For the other islands this line is intended to show only that movements occurred before Tertiary *e* 5, but the exact

[18] J. H. F. Umbgrove, "Palaeogeographie der Oceanen," *Tijdschrift Kon. Nederl. Aardrijksk. Genootschap*, Vol. LIV (1937), No. 4, pp. 489–534.
L. J. Chubb, "The Structure of the Pacific Basin," *Geological Magazine*, Vol. 71 (1934), p. 289.

time at which they took place can not, as may be understood, be given with any certainty in the present state of our knowledge, and it may have been very divergent for different islands. This clearly proves one fact, namely, we can not give a clear, connected picture of the movements that took place in the East Indian Archipelago during the Paleogene. In this regard we are a little better informed about the Neogene.

NEOGENE

The Miocene transgression (Figure 10).—However different the Paleogene history of several areas may have been, it is clear that, during the Lower Neogene, shallow seas were widespread and in many places had a transgressive character (*cf.* Table VI).

Figure 10, wherein an effort has been made to give an outline of conditions during Tertiary *e*, may serve as an illustration. Many authors have spoken of the Beboeloeh transgression, after Beboeloeh, in Eastern Borneo, the locality from which the marine Tertiary *e* 5 foraminifera were first described by the present author (1927).

Meanwhile, the unconformable character is very striking in South and Central Sumatra, and, as one of the first well defined localities is situated in the Batoeradja limestones, we speak of the Batoeradja transgression. Notwithstanding the blank parts, we need but little imagination to see that we are here confronted with a sea which invaded the areas of Sumatra and the Nias-Mentawei islands from the west and southwest.

On the other hand, very little is known about the distribution of Tertiary *e* 5 on Java. The lack of this horizon in the section of the Djiwo and the Loh-Oelo Mountains, for example, might point to the fact that, at the time, parts were not submerged by the sea; but in any case it is impossible to fix the boundaries between land and sea to the slightest degree. And on the lesser Soenda Islands there is only one indication of the occurrence of Tertiary *e*, namely, on Flores.[19] In default of sufficient exact data, some areas where Tertiary *e* probably does occur, such as the Philippines, Obi, Halmaheira, and Batjan, have been left blank. This is also true of Western Celebes. On the Bird's Head of New Guinea only one occurrence of this age has been indicated. Lastly, a number of places are marked with a point of interrogation, namely, those in which it can not, as yet, be proved with certainty whether Tertiary *e* or Tertiary *f*, or both occur, and which consequently have been marked "?" on Figure 10.

The Miocene folding (Tertiary f) (Figure 11).—After the sedimen-

[19] The exact locality of this occurrence is not mentioned in Ehrat's paper (1925). The locality I marked on Figure 10 is entirely arbitrary.

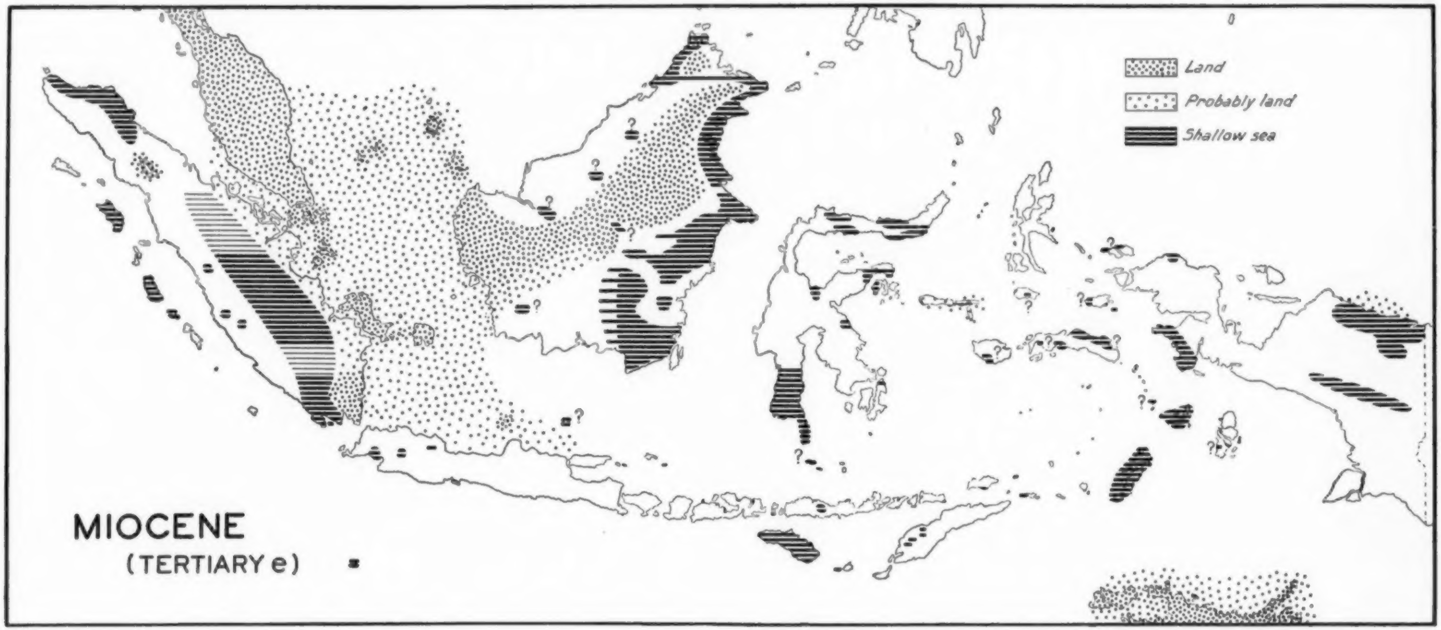
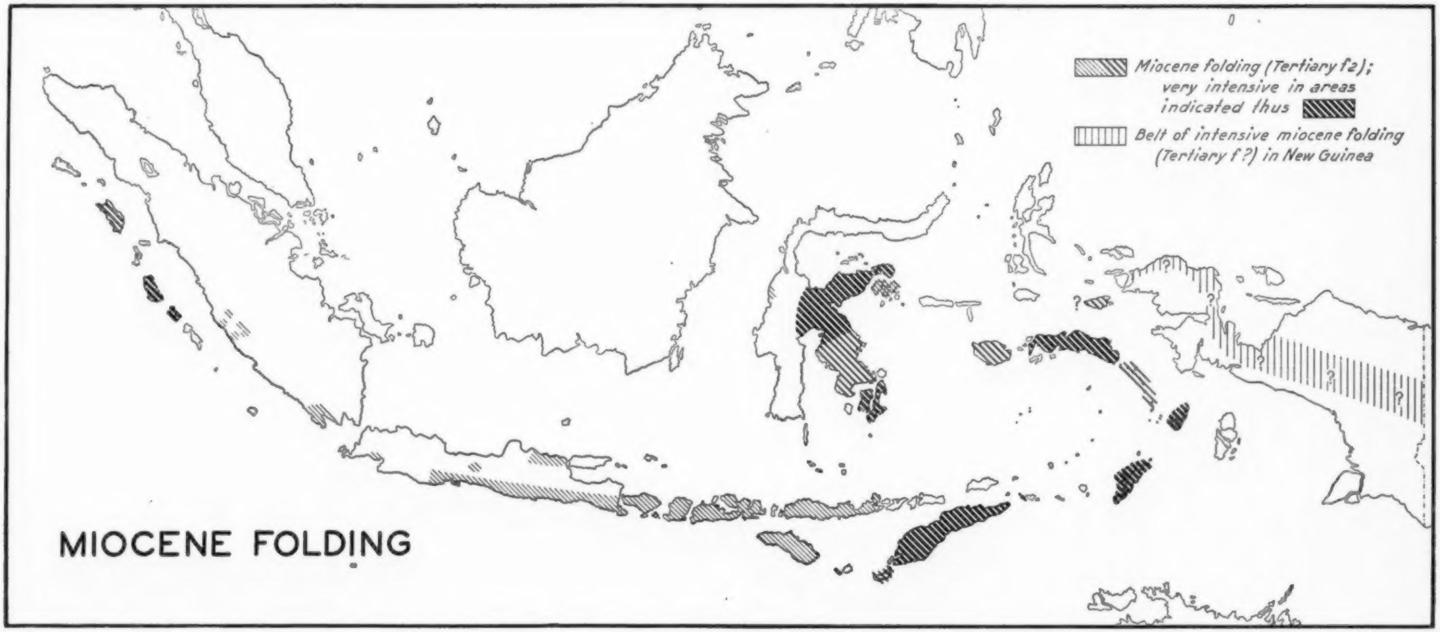


FIG. 10



Miocene folding (Tertiary f2); very intensive in areas indicated thus
Belt of intensive miocene folding (Tertiary f?) in New Guinea
MIOCENE FOLDING

Fig. 11

tation of Tertiary *e* and part of Tertiary *f*, a period of the most intensive folding that occurred during the Neogene began. We may probably fix it in Tertiary *f* 2.

In Table VII several areas have been included where this folding has been met with, while Figure 11 further illustrates this. Of Timor, Letti, the Tanimber Islands, Ceram, and Boeton, especially, it is known that the folding of the sediments must have been very intensive. In these areas overthrust masses are known or supposed to exist.

On the other hand, it has been established that a much less intensive folding occurred in other areas in strata of the same age, as in the western part of South Sumatra, South Java, and on Soemba. A comparison of the diagrammatic sections 1, 2, 6, and 7 (Plate 1) shows these differences in intensity more strikingly (all the more so as the section through Timor, for example, must be regarded as decidedly more diagrammatic than that through South Sumatra).

What we are now able to study on the surface, that is to say, on the islands, are only parts of an originally connected whole. Are they the remnants of a Miocene folded chain of mountains that wound itself through the area of our present archipelago but which was broken up by occurrences which we shall consider more fully later on, so that some parts are now situated deep under sea-level, while others were lifted high above it? The exact boundary of that zone can not in any case be given, even less so where new data appear again and again. The picture given in Figure 11 may be found in a former publication (1934). Misool and neighboring islands have now been added, as new localities, where Miocene (including at least Tertiary *e* 5) appears to have been folded into distinct anticlines and synclines (information by Dr. Fr. Weber) while Dr. Schuppli has informed me that an unconformity in Tertiary *f* has been found in Northern Java and Western Celebes (Lariang). The communication by Hetzel that fragments of Miocene rocks (Halang series) have been found in Miocene conglomerates in western Central Java, points in the same direction. Lastly, van Bemmelen located this Upper Miocene unconformity in North-Central Java, according to a recent publication (1937). So I prefer to do no more than note down the data and keep away from hypothetical reconstructions.

We do not know the answer to many important questions. Was this area of folding continued from the eastern arm of Celebes to the Philippines? Of the islands that might be regarded as remnants of this area and which might thus furnish us with data (Tofoere, Mojaoe, Talaud), the geology, especially the age of the sediments on Talaud, is too insufficiently known to admit of a fixed conclusion in any direction.

Then: has the intensively folded and intricately built "spinal column" of New Guinea been folded at the same time? It is possible, but the data do not yet admit of a conclusion.[20] The folding might, for example, have taken place in a more recent part of the Miocene. That is the meaning of the series of marks of interrogation that I have inserted in Figure 11.

And supposing that, before long, it should be proved that this period of folding was indeed the same as that of the zone wherein East Celebes, Ceram, the Kei Islands, *et cetera,* are situated, should we conclude that these two folded mountain chains were connected? And where?

Where are we to look for the continuation of New Guinea's spinal column towards the west? We can not know the answer until our geological knowledge of the Northern Moluccas, especially of Halmaheira and the islands situated between New Guinea and Halmaheira, has increased considerably. On the other hand we can trace the East Indian zones to the west (Burma). We shall go into this more exhaustively in Chapter IV.

Paleogeography after the Miocene folding.—Now let us try to form a picture of paleogeography after the Miocene folding. Erosion had gradually advanced so much that parts of the Miocene area of folding had been worn down to low relief. Thus in South Java we see again sediments of a shallow transgressive sea from Upper Tertiary *f*, resting unconformably on the older Tertiary (Section No. 6). And the same is perhaps applicable to the lesser Soenda Islands[21] (in so far as we know), and Soemba.

On the other hand, other islands belong at the same time to an area of denudation. This is, first of all, true of the zone that we can follow from Eastern Celebes via Ceram, the Kei and Tanimber islands to Timor; and of the series of islands west of Sumatra. As a single remnant of the region in between, Christmas Island furnishes us with the same conclusion. Lastly, we wish to point out that probably the greater part of the western strip of Sumatra also formed part of this area of denudation (Table VII).

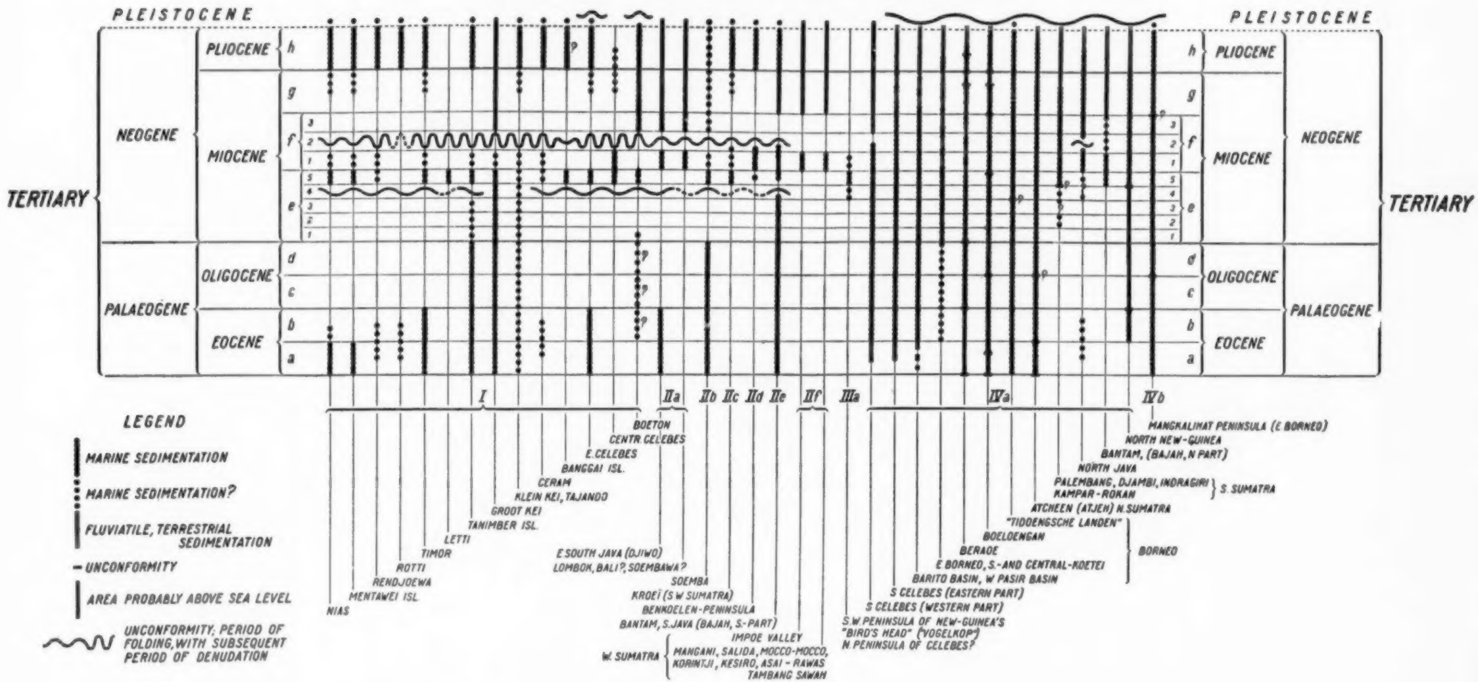
THE TERTIARY OIL-CONTAINING GEOSYNCLINES

The Lower Neogene denudation products were, in considerable part, accumulated in remarkable geosynclines, the situation of which is not always clearly demonstrated in a paleogeographic picture. They

[20] The folding, in any case, took place after Tertiary *e* and probably before Tertiary *h* (see the discussion of Tertiary *h*).

[21] On the lesser Soenda Islands there are insufficient data to determine whether Tertiary *f* does indeed belong to Tertiary *f* 3.

TABLE VII
DIAGRAMMATIC SUMMARY OF TERTIARY STRATIGRAPHY



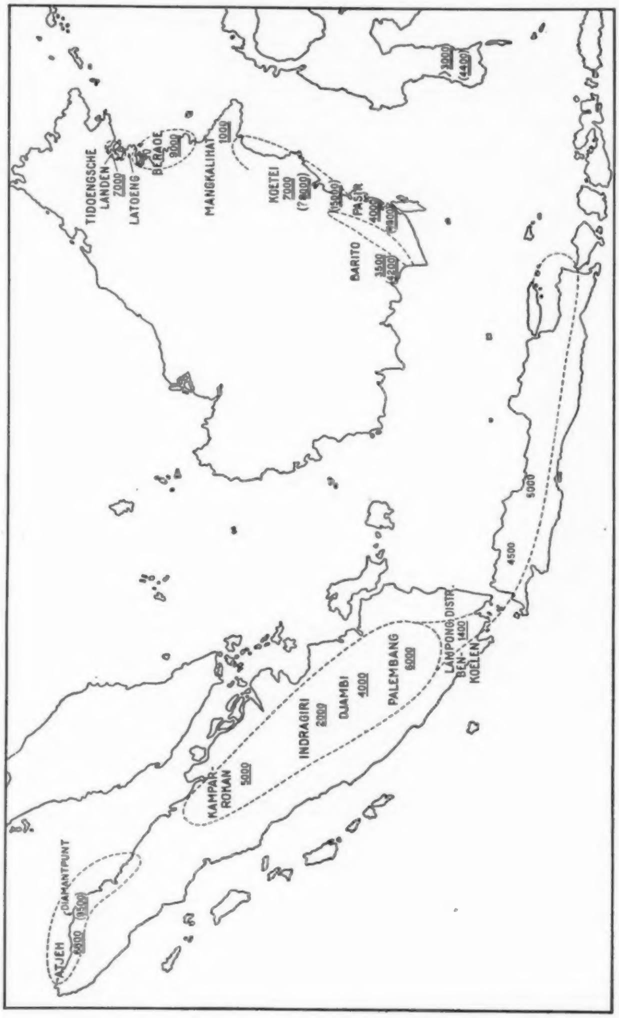


FIG. 12.—Geosynclinal basins in the western part of the East Indian Archipelago. Explanation in the text.

are areas where the substratum sank gradually and thus gave rise to the accumulation of some enormously thick sediments. The subsidence of the bottom of these basins or troughs of strong sinking and sedimentation began in the Eocene, or in some places in the Lower Miocene, Tertiary *e*.

In Figure 18 the situation of these geosynclines is represented. They were folded towards the end of the Pliocene (see Sections 3 and 4). It is the combination of enormously thick sediments and a not too intensive folding that predestined them to be hopeful areas for oil research. Indeed, the most important oil fields are situated in these regions. The subsidence, filling up with sediments, and the ensuing period of folding of these geosynclines have been terminated, geologically speaking, within a very short time.

In Figure 12 a sketch map of the most important of these basins is given; the figures indicate the thickness of the Neogene sediments; the figures between brackets indicate the thickness of the whole Tertiary. Where the figures are underlined the "geosynclinal" subsidence began during the Miocene; where doubly underlined, during the Eocene; where not underlined (as in Java), the time of the beginning of the subsidence is not known with sufficient certainty, though probably it began in the Miocene. The subsidence and sedimentation lasted in each case until the end of the Tertiary, after which followed a period of gentle folding (Sections 3 and 4).

These figures clearly show that the intensity of sedimentation and the amount of subsidence which can be deduced from it have been much more marked in the Neogene than in the Paleogene.

These Tertiary basins of sedimentation are filled principally with neritic and partly with hemipelagic deposits, also limnic, lacustral, and terrestrial deposits in some places form an important part of the sediments (Table VII). Abyssal deposits do not occur at all.

The strong subsidence and sedimentation begins everywhere in continental regions. Thus, for example, the geosynclinal series begins with fluviatile-terrestrial sedimentation in the Barito basin (Southeast Borneo) and the south of Celebes. In other places the lowest strata of the geosynclinal series consist of marine, that is, neritic sediments of a transgressive epicontinental sea.

These Tertiary geosynclines do not form continuous strips or zones, but they are basins or troughs with a strong subsidence and sedimentation. That the three basins of sedimentation situated along the east coast of Borneo have each had individual development and were separated from each other by submarine ridges (notation IV b on Table VII) has been argued by Leupold and Van der Vlerk. According

to these authors the individuality of these areas manifests itself clearly in the differences of their stratigraphic profiles—which is schematically shown in Table VII—and is also evident from the facies and thickness of the sediments deposited on the ridges between them.

Atjeh, the south part of Sumatra, and the north part of Java may also have belonged to three different basins of sedimentation.

The difference between the development and the stratigraphic profiles of the Tertiary in Atjeh and Southern Sumatra has already been pointed out more than once. This argument alone pleads for the individuality of these geosynclines.

No Neogene is to be found along the sides of Lake Toba. Therefore a possible connection between the trough of Atjeh and that of south Sumatra would have to be looked for entirely east of Lake Toba, where, however, the older strata are hidden by a sheet of volcanic ejectamenta.

Perhaps a geosynclinal connection exists between the geosynclines of central to Southern Sumatra and Northern Java. In this strip a thickness of 1,000–1,800 meters of Miocene (Tertiary *e*) has been ascertained locally. So perhaps there has existed a geosynclinal connection, albeit narrow, not deeply subsided, and only temporary, between Southern Sumatra and Northern Java, by way of the peninsula situated between the bays of Semangko and Lampong. On the west, in the south part of the residency of Benkoelen, this folded Miocene series is covered by a thin transgressive layer of unfolded marine "Pliocene." Van Es has presented strong arguments that the Strait of Madoera forms a submarine continuation of the North Javanese geosynclinal area. In Bantam Koolhoven mapped the southern margin of the Javanese geosyncline. It is evident from the stratigraphic sections of the Tertiary as well as from the paleogeography before the origin of the basins, that the accumulation of thick sediment layers became possible as a result of the subsidence.

Thus, for example, the lower layers of the geosyncline in Palembang, Djambi, and Indragiri are formed by the neritic (littoral) Neogene limestones (Tertiary *e* 5) of a shallow sea, which was, however, in its wider extent, not limited to a strong subsidence, but covered unconformably a much more extensive area. If the filling up with sediments keeps step with the subsidence of the bottom, the facies remains the same; if the subsidence surpasses the rate of sedimentation, rocks originate that represent a deeper facies; in the reverse case a shallower facies occurs, perhaps ending in the area becoming land.

As an instance I add this description which Rutten gave in 1927 of the movement of the geosyncline in the district of Palembang.

The first transgression indicating the origin of the geosyncline begins with the littoral *Lepidocyclina* limestones; soon, however, the geosynclinal subsidence surpasses the speed of the sedimentation, and reef limestones can no longer grow there; in a deep, but still continually subsiding sea, the Goemai layers, which are 3,000 metres thick, are deposited. Gradually the sedimentation begins to gain on the geosynclinal subsidence and, during the period of the Lower Palembang strata, quite a number of sandy sediments,

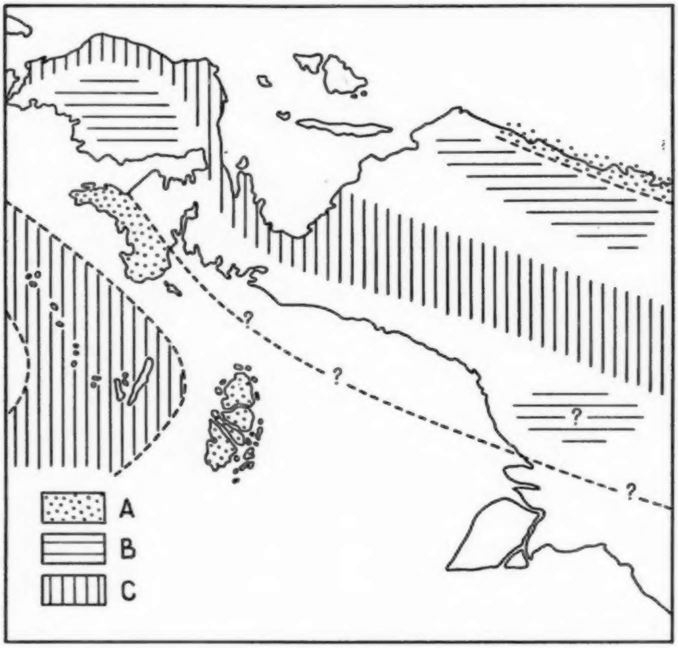


FIG. 13.—Sketch map of New Guinea and adjacent islands showing: A, regions where the Neogene has hardly been folded if at all (compare Section 5); B, geosynclinal basins folded towards the end of Tertiary times; C, geosynclinal belts folded in the Miocene.

containing the fauna of a quiet but shallow sea, originate by the side of clayey sediments. With the beginning of the Middle Palembang strata, the geosynclinal subsidence becomes relatively so small that the sediments deposited acquire a continental character, and at the time of the Upper Palembang strata this continental character continues, to end in the folding of the Neogene. Thus the geosynclinal subsidence was greatest during the lower Neogene, diminished gradually, and at last—shortly before the beginning of the folding—was finished entirely.

In the basin of North Sumatra the terrestrial facies does not occur before the end of the Pliocene; in southern Sumatra it occurs in Upper Miocene, in the basin of Beraoe and, farther south, in Koetei, an alternation of marine and fluviatile terrestrial sedimentation was taking place as early as Lower Miocene. On Table VII this is indicated diagrammatically.

Little is known of the extent and the exact age of the Recent sediments in the basins of the Bird's Head and Southern New Guinea (Fig. 13). According to David the sedimentation in the basin of southern New Guinea has continued up to the Pliocene, and this faintly folded series is covered unconformably by Pleistocene deposits. As regards the island Waigeoe, the period of folding can not be indicated with any certainty; Pliocene rocks may belong to the folded series of sediments.

PLIOCENE

PALEOGEOGRAPHY (FIG. 14); PLIOCENE "GRABEN" IN THE SOUTHERN MOLUCCAS; GEANTICLINE OF WEST SUMATRA AND SOUTH JAVA

The emergence of geosynclines just discussed originated a considerable expansion of low marshy areas in the Pliocene. In the basin of Atjeh and in Northern Java marine conditions continued for a longer time. This has been indicated on the map for the Pliocene (Tertiary *h*) (Fig. 14). Conditions are, however, very intricate, especially on Java. Especially in the higher horizons a strong change of facies in marine brackish and fresh water deposits occurs, within a short distance. Of this a table in one of Van Es' publications, *The Age of Pithecantropus* (1931), gives a clear idea. But even if we possessed exact information about the distribution and age of these sediments, it would be impossible to plot them on a map the size of Figure 14.

According to Van Es the Javanese southern mountains rose above the sea during the entire Pliocene. This is probably also true of at least parts of Bali and Lombok. The data regarding Soembawa, Flores, and the eastward series of islands of the so-called Inner Banda arc are so incomplete that I prefer to leave a blank on the maps concerned. In the southern part of Sumatra (Benkoelen) and in Southwest Java (Bantam) sediments of a shallow transgressive sea occur (Section 7).

We can not be certain whether, during the Pleistocene, marine conditions prevailed in the geosynclinal basins of the Bird's Head and of Southern New Guinea mentioned before, or whether land conditions existed. The numerous Foraminifera-bearing rocks, for example, of the Bird's Head, described by Rutten (1924), belong to higher horizons than the *Lepidocylina*-bearing Tertiary, but their age can not be fixed exactly.

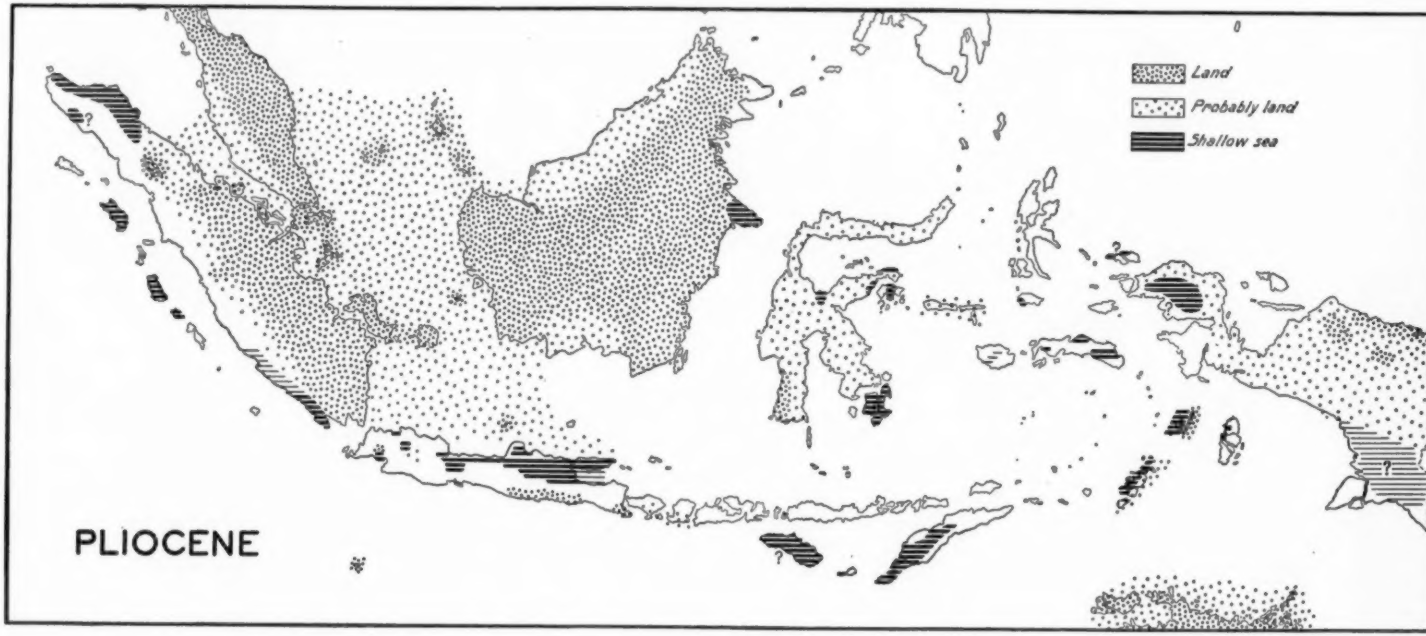


FIG. 14

The denudation of the areas folded during the Miocene generally appears to have proceeded so far in the Pliocene that the sea could invade them; it is especially instructive to compare the series of islands west of Sumatra and the series of Timor, Tanimber Islands, Ceram in Figures 11 and 14. It is exactly on certain islands of the so-called "Outer Banda arc" that the sedimentation of the marine Pliocene appears to have been favored by the formation of trough faults and graben wherein a thickness of, in places, some hundreds of

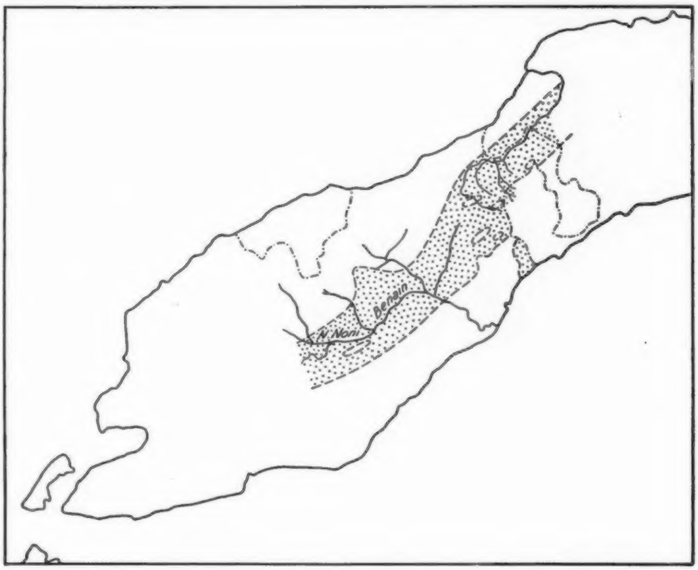


FIG. 15.—Sketch map, showing the area of Upper Tertiary deposits in Central Timor. (After Molengraaff.)

meters of neritic sediments can be measured now. The situation of these trough faults and graben well-nigh parallel to the longitudinal axis of the present islands on Timor, the Tanimber Islands, and the Kei Islands is pictured in Figures 15, 16, and 17.

On Timor (Fig. 15) the Pliocene and Pleistocene deposits are not, or are very slightly, folded with the exception of a steep distortion of the Upper Tertiary at the sides of the basins or "graben." They have been raised to a considerable height, however, during the later Pleistocene, in Central Timor, for example, to 1,280 meters above sea-level.

Briefly we can summarize these movements as follows: after the Miocene period of intensive folding followed a period of elevation combined with denudation and levelling of the landscape. Then, during the Pliocene, subsidence, formation of faults (graben) occurred

FIG. 16.—Sketch map, showing the Pliocene trough in the Tanimber Islands. Mud volcanoes are indicated by crosses. (After Fr. Weber.)

and, finally, towards the end of the Pleistocene, again elevation above the level of the sea and faulting.

Likewise, as on Timor, a trough-shaped depression in the Pliocene appeared on the spot where the Tanimber Islands are situated now.

This depression was filled up with marine sediments, resting unconformably on the intensively folded older Neogene. Figure 16, composed according to data furnished by Dr. Weber, gives a diagrammatic picture of this.

As a third example (Fig. 17) we may examine the Kei Islands somewhat more closely. According to Weber's data neither Eocene nor Pliocene occurs on the islands of the western zone, Koer and Fadoh; continual sedimentation from Lower Eocene to within the Miocene

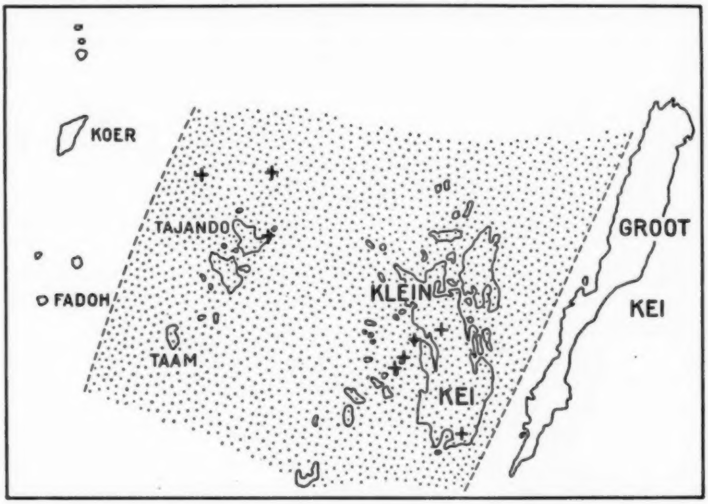


FIG. 17.—Sketch map, showing the Pliocene trough in the Kei Islands. Mud volcanoes are indicated by crosses. (After Fr. Weber.)

(at least Tertiary *e*, probably also part of Tertiary *f*) took place in the central as well as in the eastern zone.

After the ensuing period of intensive folding which is met with in the whole of this area (Table VII), Groot Kei was raised and remained above the level of the sea; in the central zone, on the other hand (Klein Kei and Tajando) a trough-shaped subsidence occurred, marine Pliocene was deposited, and slightly folded towards the end of the Pliocene.

I want to point out in a few words that upraised Plio-Pleistocene marine deposits are also known in other areas. We know, moreover, that their origin was, in Ceram and perhaps also in Boeroe and Celebes (Posso), attended with the formation of analogous graben.

In opposition to this, Western Sumatra and the southern strip of Java must, in general, be taken as a zone where land conditions predominated. During the Upper Neogene Western Sumatra and Southern Java formed part of a zone with a tendency to rise (a so-called geanticline) opposed to the geosynclinal zone folded towards the end of the Pliocene, which was situated north of it. Lehmann concludes:

Der Unterschied in der morphologischen Entwicklung der südlichen und der nordlichen Tertiarzone in Java besteht in der Hauptsache darin, dass jene nach der Faltung im Obermiocän nur mehr eine gross räumige Deformation mit starker vertikale Komponente erfahren hat, während diese seit dem obersten Pliozän einer Detailfaltung unterlag, in dessen Gefolge das Neogen wohl über den Meeresspiegel, aber nicht in grössere Höhe gehoben wurde.[22]

Where, in the geanticlinal area, marine Pliocene was still being deposited, this was elevated later on (Southwestern Java), in Benkoelen (Southwestern Sumatra) in a terrace, faintly sloping seaward.

I will not here enter into the gravimetric characteristics of the different areas. It may be mentioned here, however, that after the publication of Vening Meinesz' *Gravity Research in the East Indies* another interesting communication about gravity research in Java was published by Vreugde.[23] The connection between geology and gravity field appears very clearly and more in particular in a map published by Vreugde in which the well known contrast between the northern geosynclinal area and the southern geanticline on Java is striking.

THE FOLDING TOWARDS THE END OF THE PLIOCENE

The expression, towards the end of the Pliocene, is vague, but it can not be improved so long as an exact correlation of the East Indian Neogene and Pleistocene deposits with their European equivalents meets with unsurmountable difficulties. Exact criteria failing, it is an open question where we should draw the division between Pliocene and Pleistocene.

We can only say this much: a series of Tertiary sediments, to which Pliocene sediments undoubtedly belong, were folded during a time that we shall have to call either Upper Pliocene or Lower Pleistocene. On Table VII the stratigraphic sections folded "towards the end of the Pliocene" have been grouped together in the series under Figure IV, the dotting of the upper horizontal line indicating the uncertainty of the boundary between Pliocene and Pleistocene. This

[22] H. Lehmann, "Morphologische Studien auf Java," *Geographische Abhandelungen*, 3e R., No. 9 (1936), p. 112.

[23] L. M. H. Vreugde, "Quelques anomalies de pesanteur dans le nord de Java," *VII Congres international de Menes*, etc., Paris (1935), *Section de Géologie appliquée* II, pp. 919–26.

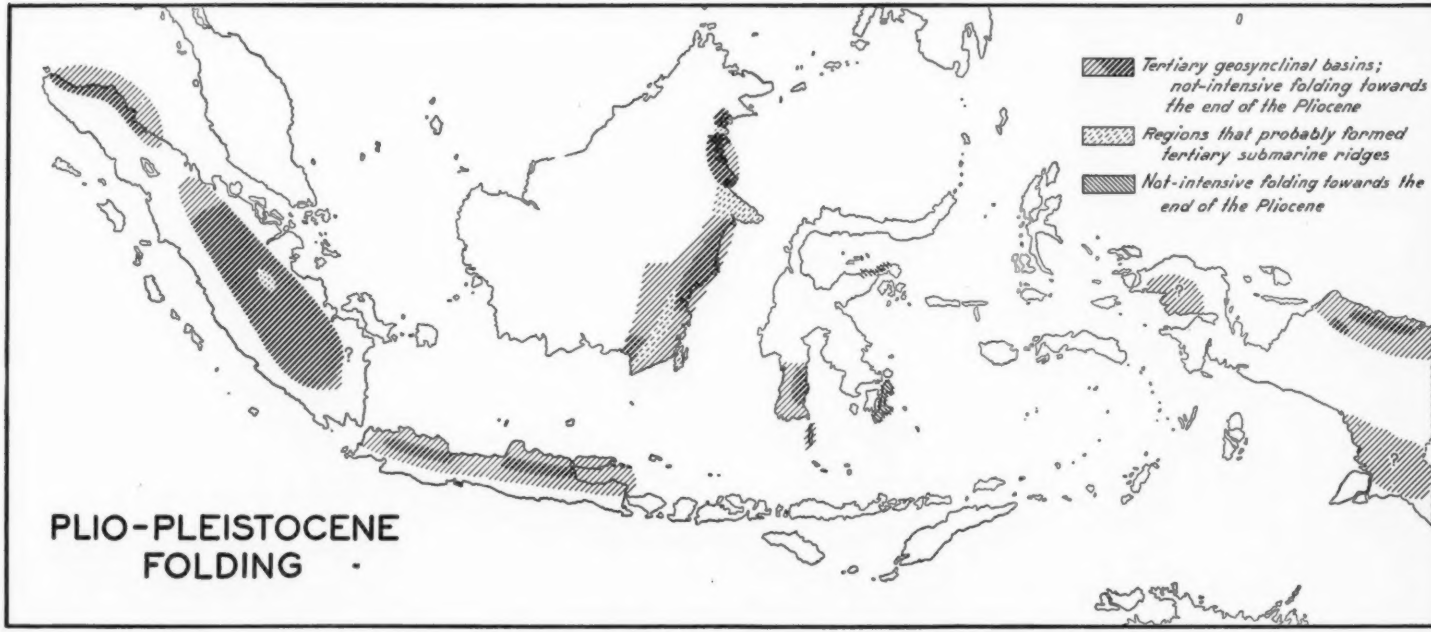

Tertiary geosynclinal basins; not-intensive folding towards the end of the Pliocene
Regions that probably formed tertiary submarine ridges
Not-intensive folding towards the end of the Pliocene
PLIO-PLEISTOCENE FOLDING

FIG. 18

period of folding is characteristic of the Tertiary geosynclinal basins we discussed before and whose situation is shown on Figure 18. This folding is not intensive; it is, for example, much less strong than the Miocene folding on Timor, as is illustrated by a comparison of Sections 3 and 4 with Sections 1 and 2, which furnish a diagram of the much more intensive Miocene folding on Timor and Eastern Celebes.

Outside the typical geosynclinal basins a gentle folding of the sediments towards the end of the Pliocene has been established in the eastern half of the East Indian Archipelago; in the eastern arm of Celebes, by Koolhoven (Section 2) and on Boeton by Hetzel.

The character of the Neogene deposits of the eastern arm of Celebes (Pliocene so-called molasse, with a maximum thickness of 3,000 meters (Section 2) and of Boeton (Miocene and Pliocene conglomerates, sandstones, and marls without tuffs to a maximum thickness of 2,000 meters) diverges in such a degree from the series of sediments of the geosynclinal basins discussed heretofore that I indicated them with a different notation on Figure 18. The Neogene sediments of Boeton contain asphalt which, according to the geologist who studied this area, originates in Triassic oil-bearing layers (Hetzel, 1936). According to a chemical examination, however, it appears to be of Tertiary age (Thoenes, 1936).

A weak folding with great amplitude of the Pliocene Foefa beds of Ceram was further mentioned by Rutten; perhaps this applies also to the sediments, regarded as Pliocene, on Boeroe. Lastly, Weber mentions that the Pliocene of the Tanimber and Kei islands has been "moderately and weakly" folded. On Figure 18 and Table VII these very weak movements have consequently not been marked. They are, moreover, associated with masses of sediments of little thickness (a few hundreds of meters).

DENUDATION OF THE FOLDED AREAS; MOST RECENT MOVEMENTS

Of course the folded areas were immediately affected by erosion. The following quotation from Rutten (1927, p. 128) may serve as an illustration:

> We know Pliocene deposits, among others to the north and south of the marly ridge Soerabaia-Semarang, and if we connect these Pliocene deposits with each other through the air, we come to the conclusion that in the Quaternary an average of more than 2,000 meters of Tertiary folded mountains must have been denuded.

The result must have been a peneplain which was situated but little above sea-level. But with this we have not reached the present situation. Rutten has been able to depict and describe (1927, p. 130

and Fig. 37) how this peneplain in Semerang, with the volcanic products of the Oengaran volcano resting on it, has been elevated almost vertically to a height of 100–200 meters. Herein the present valleys have cut their courses. In Atjeh the amount of this elevation appears to be about 1,000 meters (Rutten, 1927, pp. 423–25.) The geanticlinal areas, such as the so-called Barisan Mountains of Sumatra and the southern strip of Java, are even more strongly characterized by a tendency to be elevated. We have mentioned that the transgressive Pliocene of Benkoelen (Southern Sumatra) has been raised to a terrace with a faint seaward slope (Section 7).

Lehmann exhaustively described how the elevation of the southern mountains on Java, an area that probably has remained above sea-level since the Pliocene, was attended with a faintly undulating warping of the original peneplain. This author gives an interesting discussion of the Karst phenomena in this Javanese southern chain of mountains. In doing this, he endeavors to derive the remarkable distribution and morphology of the Karst phenomena from that movement and warping of the surface. Let us take one more example. In a section through an area in the northern part of Central Java (Karang-Kobar region) Van Bemmelen (1937) depicted recent upwarping of the surface layers which he supposes to be of an Upper Pleistocene and Holocene age.

So the relief of Sumatra and Java has been accentuated into a landscape which, with its ever increasing series of volcanoes, agrees in its essentials with the present.

NEOGENE BATHOLITHIC INTRUSIONS; ON THE ORIGIN OF THE RECENT ZONES OF VOLCANOES

Although the data are few in number, it is an established fact that large intrusions of granite originated in the Upper Neogene. In Southern Sumatra such a batholith with diameters of 17×22 kilometers occurs in the Barisan Mountains in the basin of the rivers Semangka and Pintau.

This mass is of a more recent age than the andesitic formation with its intercalations of Lower Miocene beds (Section 7) through which it has broken away and where it caused contact metamorphism. An exhaustive description was given by Westerveld (1933).

A Neogene age has either been established or is seriously postulated of some other granite intrusions in Sumatra. Koolhoven described post-Lower Miocene deep-seated rock from Western Java, Harloff described them from Central Java, and Van Bemmelen mentioned some smaller hypabyssal gabbroidic and gabbrodioritic intrusions

FIG. 19.—Distribution of the active volcanoes in the East Indian Archipelago. (After Stehn.)

from northern Mid-Java (Karang Kobar). According to the latter author (1935) Hartmann found recent granite masses on the island Alor north of Timor as well, but, up to now, we lack further data from there.

Western Sumatra and Southern Java belong to a zone where the Miocene folding was not very intensive (much less strong than in the Timor-Eastern Celebes zone). They are, moreover, areas showing a clear tendency to rise during the Upper Neogene, so-called geanticlines, as mentioned in a previous paragraph.

It is in this zone and partly also in the geosynclinal areas situated immediately north of it (discussed before) that the Neogene intrusions are situated and where now an imposing series of volcanoes can be traced from Northern Sumatra to the Banda Sea (Fig. 19).

It is probable that the origin of the batholiths is connected either with the Miocene period of folding, or with the later geanticlinal upwarping of Western Sumatra and Southern Java or with both phenomena. It is very probable that the recent volcanism may be historically derived from the Tertiary plutonism and volcanism known of those islands.

I must point out here, however, that the distribution of volcanism in the successive horizons of the Tertiary has never been summarized satisfactorily. And yet, such a summarizing study, not influenced by a presupposed hypothesis, must be considered of fundamental importance in order to obtain a good insight into the origin and appearance of present volcanism. I am indeed convinced that such an extensive study will have to be undertaken before it is possible to attempt to give a well based explanation.

The distribution of the recent volcanoes forms only part of a much bigger problem. For volcanism occurred, moreover, in areas where now only extinct volcanoes occur which can still be recognized morphologically, for example, in Southern Celebes and Eastern Borneo, and even in marine Tertiary areas where at present there is a total lack of volcanism, as in Northern Dutch New Guinea.

MOST RECENT GEOLOGICAL HISTORY OF THE EASTERN HALF OF THE ARCHIPELAGO. ORIGIN OF DEEP-SEA-BASINS

Let us now turn our attention to the eastern part of the archipelago, where we shall find examples of important recent movements.

Leuchs regards faulting and the subsidence of vast areas as one of the most important characteristics of the youngest geological history of eastern Asia's marginal areas. He says:

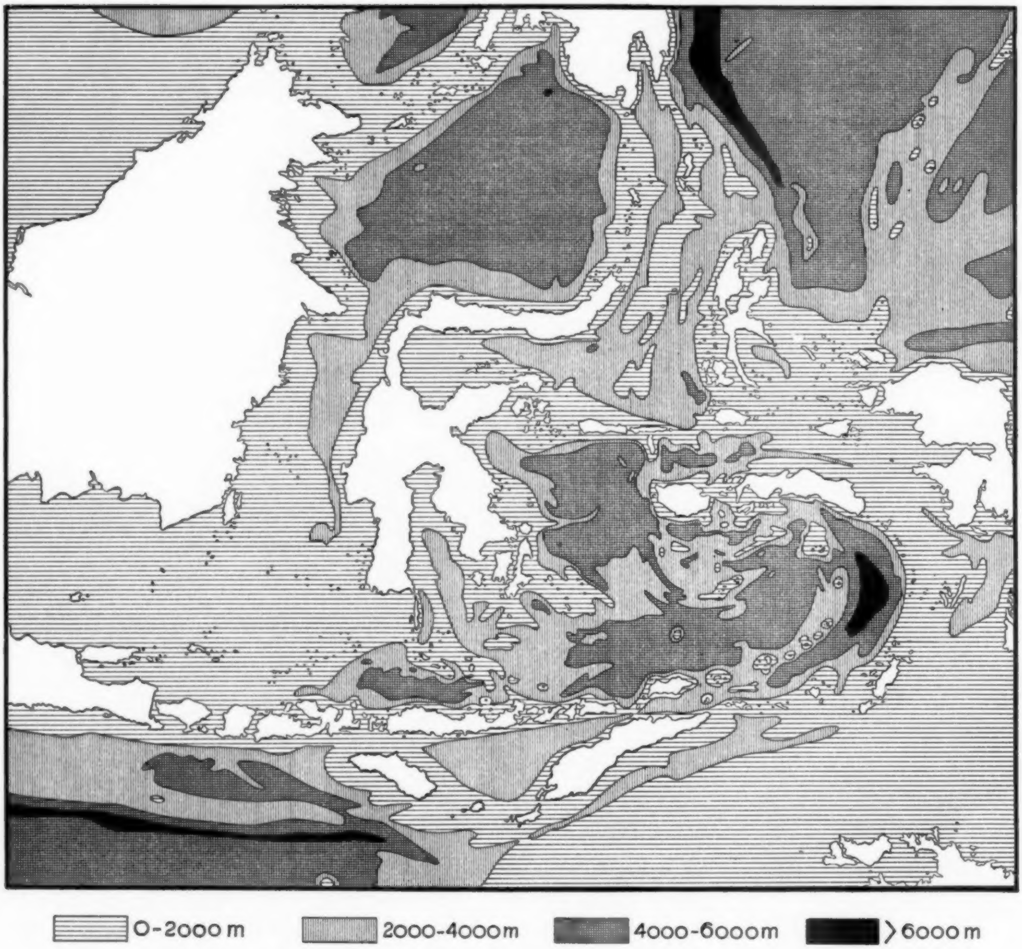


FIG. 20.—Deep-sea relief in the eastern part of the East Indian Archipelago. (Adapted after van Riel.)

Junge Zertrümmerung beherrscht die ganze Region, grosse Gebiete sind unter den Meeresspiegel gesunken, im Süden ist ein Archipel an die Stelle des Kontinental-gebietes getreten.[24]

It appears to me that the facts do indeed force us to this conclusion, not only for the East Indies but also for the neighboring Melanesia.

Figure 20 shows the shape of the deep-sea basins, according to Van Riel's bathymetric chart (1934).

If one tries to imagine that the bottom of the present deep-sea basins, such as the Banda Sea or the Weber trough, should be elevated above the sea or upfolded, one realizes that a series of rocks, for the greater part of bathyal or abyssal facies, would appear to view.

Conversely, we concluded from the occurrence of bathyal and abyssal sediments among Mesozoic rocks of many islands that, during the Mesozoic, deep-sea basins must have existed within the bounds of the present archipelago.

But nowhere did Tertiary sediments, which rose to the surface either by intensive upfolding of the original sea-bottom, or by a gradually elevating movement, furnish data for such a conclusion.

On the contrary, the marine sediments we know from the Tertiary of the entire archipelago are littoral and neritic rocks, deposited in a shallow sea.

Some authors have argued the possibility that some of the Miocene *Globigerina* marls of Sumatra, Java, and Borneo may have originated hemipelagically, perhaps even bathyally. But facts like those mentioned by Rutten about Eastern Borneo prove that here, too, we certainly have to do with sediments deposited in a shallow sea, merging into terrestrial facies in a short distance. These are the gastropod fauna in the *Globigerina* marls, among which occur even brackish and fresh-water species, with oblique cross bedding of the deposits (1927, p. 708).

Verbeek (1908), too, regarded a basin like the Banda Sea as a phenomenon of subsidence. His hypothesis that this subsidence was the cause of the folding of the Miocene rocks on the surrounding islands has, however, been disproved by the facts, now that we know the period of folding more exactly. As already mentioned, the sequence of the occurrences is the exact reverse of what Verbeek supposed it to be.

Even in the areas where the very intensive Miocene folding took place (Fig. 11), the facies of the sediments shows that the bottom was never situated at a great depth below the level of the sea.

From these facts alone it is evident that the present deep-sea relief

[24] K. Leuchs, *Geologie von Asien*, I (1935), p. 33.

of the East Indian Archipelago is a characteristic that must have originated during the recent geological past.

We may further mention the fact that in several places the trend of the folded Miocene is intersected at an angle by the present coastline of the deep basins, from which it follows that those basins must have originated at least after that Miocene folding. Molengraaff explained, for example, that in Timor, the Amanoeban mountain chain is intersected at an angle of 12° by the coast. His generally accepted opinion is, that the origin of the deep-sea basins and the elevation of the series of islands between them, must have occurred simultaneously.

It is difficult to determine when, exactly, these submergences began. Perhaps the beginning may be fixed in the Pliocene. Wanner thinks that the deep sea which separates Misool and New Guinea from Ceram originated during the "Pliocene-Pleistocene"; the fractures observed on Misool date probably from that time. The Upper Neogene of the island Boeton (Southern Celebes) has been folded with a trend that intersects at right angles the neighboring Gulf of Boni.

The origin of the Pliocene graben on Timor, the Kei and Tanimber islands, and Ceram, might be regarded as phenomena that are connected with a beginning of the submerging movement of the deep-sea basins.

If, however, the submerging of the basins and the elevation of the intervening series of islands are closely connected, which is probable, then the most important part of the submerging movement must have taken place in the Pleistocene. There can not be any doubt about the fact that the rising movement of the islands took place in the Pleistocene.

This most recent movement, to mention one example that could be supplemented by many others, brought parts of the mountains in Central Ceram which were hardly situated above sea-level during the sedimentation of the marine Pliocene strata in the Masiwat-Bobot graben, to a height of at least 3,000 meters above sea-level (Rutten, 1927).

It is especially the recently elevated reef limestones that give a good impression of the amount and of the intermittent character of these recent movements. In Figure 21 some figures have been assembled for part of the Southern Moluccas.[25] The actual Pleistocene age of the elevated reef terraces has been proved in some cases.

These most recent movements manifest themselves as if—as Rutten expressed it—they were faults and epeirogenic elevations.

[25] Compiled after data occurring in publications by Brouwer, Ehrat, Kuenen, Molengraaff, Oyens, Verbeek, Wanner, and Zwierzicky.

Faintly undulating warpings of the surface layers of a type such as those mentioned in a preceding paragraph, of Java, may be established after a detailed study. Weber mentioned a weak, Upper Pleistocene undulation in the layers of the Kei and Tanimber islands. Folding phenomena which might be considered comparable with the periods of folding occurring during the Miocene and "towards the end of the Pliocene" as discussed before, can not be observed in the layers that can be studied on the surface. Again, we do not form any hypothesis as to what happened in the unknown abyssal substratum.

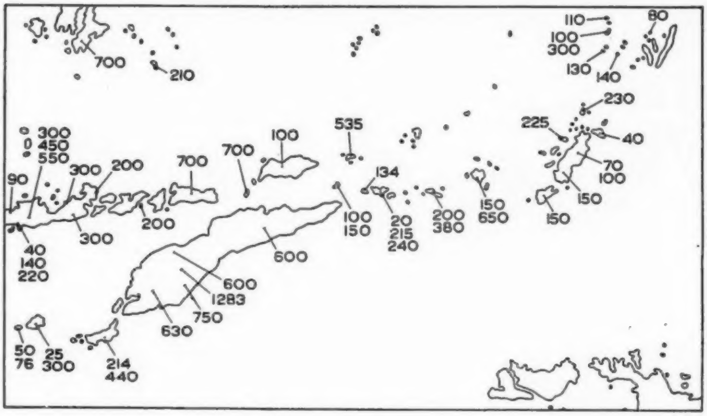


FIG. 21.—Height (indicated in meters) of elevated reef limestones.

Kuenen arrived at an analogous opinion about the origin of the deep-sea basins in his detailed study of the deep-sea relief as it has become known after the Snellius Expedition (1935). He exhaustively argues that the deep-sea basins originated recently by the subsidence of "continental" (sialic) areas.

The areas of strong positive deviations of isostasy roughly coincide with part of the most important deep-sea basins within the archipelago, the two Banda Sea basins with the Gulf of Boni, the Gulf of Tomini, the Sea of Celebes with a southern branch to the Macassar Straits, and the Soeloe Sea. And Vening Meinesz comes to the conclusion that in the areas of strong positive deviations of isostasy a considerable subsidence of the bottom must have played a part, and is still going on.

The deep-sea basin between Borneo and Celebes, too, is, geologically speaking, a very recent feature. It has been argued by many

biogeographers that the Strait of Macassar forms a line of partition between fauna and flora that is very important and has existed for a long time. The two opinions do not clash at all. This would only be the case if Borneo and Celebes had been connected by land before the origin of the deep-sea basin situated between them. The paleogeographic maps given show, on the other hand, that as early as the Miocene, even in the Eocene, an area of land in the west (Borneo) was separated from areas of land in the east by a sea (Figs. 9 and 10)—a sea of much greater extent than that which separates the present Celebes from Borneo. Rutten, too, wrote in 1916 in his detailed study of Tertiary rocks in Eastern Borneo (Koetei):

> From the fact that in the "normal" coastal strip of Koetei terrestrial deposits occur, and in the eastern areas marine deposits of Upper Miocene age are found, it may be concluded that, if the islands of Borneo and Celebes rose above the water during the Lower Miocene, they must already have been separated by a sea, and that, in the Lower Miocene, the straits of Makassar existed in embryo (1916, p. 708).

The marine sediments mentioned here were deposited in a shallow sea. As a deep-sea basin, however, Macassar Strait is as recent as all other deep-sea basins in the archipelago. Along Celebes' western coast, too, the Tertiary folded chains are intersected by the coast.

I have explained this only because Rutten's opinion has sometimes been interpreted as if the Strait of Macassar *as a deep-sea basin* dates from the Miocene. This interpretation is to some degree understandable because Rutten adds: "the same conclusion has been reached by Verbeek—on different grounds." As we mentioned before, Verbeek's supposition about the time of formation of the deep-sea basins has been disproved by the facts.

The eastern part of the archipelago, the so-called Sahoel shelf (Arafoera Sea) will be discussed further in the following pages in connection with the history of the Soenda shelf. Some remarks will be added there about the origin of the straits between the lesser Soenda Islands.

Lastly, it may be mentioned here that Van Es tried as early as 1916 to give a paleogeographic map representing conditions "towards the end of the Pliocene." He supposed that the deep-sea basins existed as such, at the time.

THE MOST RECENT HISTORY OF THE WESTERN PART OF THE ARCHIPELAGO

We have discussed the peneplain that was formed—after the folding towards the end of the Pliocene—across a considerable area in Eastern Sumatra, Northern Java and Eastern Borneo. On Molen-

graaff's suggestion, Borneo, Malaya, Sumatra, Java, and the shallow sea-bottom between is now generally called Soendaland.

In an explanation of the Pleistocene relative movements of the level of the sea on Soendaland, it is possible to reach the same result whether we assume a real movement of the bottom, or a real, so-called eustatic movement of the sea-level, or a combination of both phenomena.

Most authors think of a real change in the level of the sea. Von Koeningswald (1933) offered a hypothesis in which he proceeds from the (to him) acceptable supposition that the pole and the equator were differently situated during the Pleistocene (North Pole, 85° North Latitude, 10° East Longitude, toward the end of the Pleistocene) and that consequently the Soenda shelf may be regarded as a marginal region of Asia that was submerged by the change in the position of the equatorial girdle of water at the time of the change in the situation of the equator during the Pleistocene.

Molengraaff, on the other hand, started from the idea that in the Pleistocene, during the growth of the ice-caps, the level of the sea must have sunk, to rise again during interglacial and post-glacial times (1919). In harmony with this trend of thought, it would be possible to determine the boundary of Soendaland during the maximal sinking of the sea-level from the position of isobath of about 100 meters.

We need not here discuss the reason of the positive and negative shifting of the strand line in Soendaland during the Pleistocene. We will start from the fact that it may be considered proved that during the Pleistocene, or at least during parts of the Pleistocene, the whole of Soendaland was above sea-level.

In Figure 22 the now submerged part of the system of rivers which Van Weel constructed on the strength of the isobaths in the South China Sea, the so-called North Soenda River, has been included on one map, together with the rivers drowned in the Java Sea which I reconstructed (1929)—the East Soenda rivers.[26]

It is a well known fact that the Pleistocene North Soendanese system of streams is considered to explain the great number of similar species in the fresh-water fish fauna of Western Borneo and Eastern Sumatra. On the other hand, such a strong resemblance may not be expected between the faunas of the rivers of Southern Borneo and Northern Java, for the system of Southern Borneo and Eastern Java

[26] The recent strong growth of Java's northern coast has made it impossible to reconstruct the connection between the rivers of Java and the river beds that can be reconstructed in the Java Sea, from the isobaths.

rivers debouch separately. A temporary connection may have existed between the two which must have been situated close to their debouchment; it must have come into existence towards the end of the relative sinking of the sea-level, and must have been broken shortly afterwards with the rising of the sea-level. This forms an important contrast to the system of rivers of the South China Sea where the connection between the rivers of Eastern Sumatra and Western Borneo

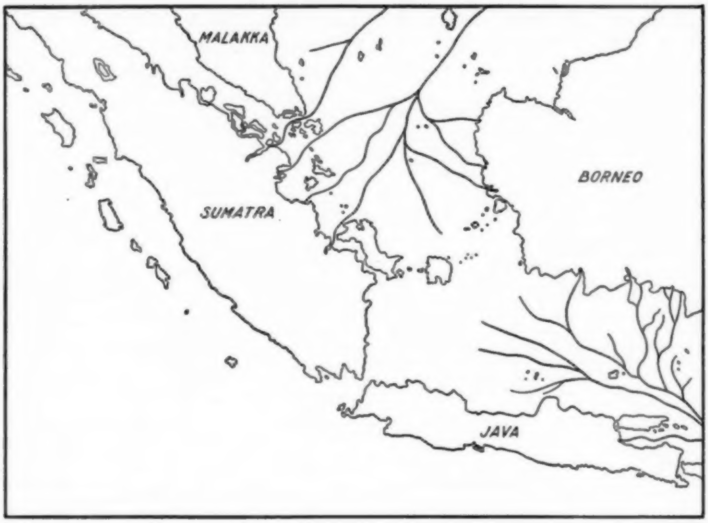


FIG. 22.—Drowned parts of Pleistocene rivers in Soendaland.

was situated much farther from the debouchment, and consequently came into existence much earlier and was broken off much later. Indeed such a striking resemblance does not exist between the fresh-water fishes of Southern Borneo and Java. Krempf and Chevey thought it possible to reconstruct a Pleistocene submarine system of rivers from the isobaths north of the Natoena Islands. They called this system: "South Indo-China River." With this they would explain the resemblance between the fresh-water fauna of Indo-China and the East Indies (1934).

Between the basins of the North and East Soenda rivers there existed a divide from Sumatra, across Banka, Billiton, and the Karimata Islands, to Borneo. This divide must, by its height, have offered great possibilities of migration to a number of animals and

plants for which the conditions of life were less favorable or insufficient in the extensive flat and low-lying area of the North and East Soenda rivers. Moreover, this land bridge between Sumatra and Borneo must have remained in existence to the very last during the rising of the sea-level, whereas the lower areas must have been submerged much sooner and the river systems dismembered.

If we suppose that the movement of the sea-level was eustatic and occurred under the influence of the Pleistocene glacial periods, we must take into consideration the recurrences of these happenings in conformity with the four glacial and three interglacial and the post-glacial periods. In that case, it is not probable that the level of the sea returned again and again to its pre-Pleistocene level, or sank to its maximum amount.[27]

In any case the reefs and coral islands on the Soenda shelf can not have originated earlier than during the Pleistocene.

Molengraaff considers the series of reefs running parallel with Borneo's eastern coast on the edge of the shallow shelf, to be a barrier reef that gradually grew upwards during the latest elevation of the sea-level (1919).

It is necessary to point out another characteristic in the relief of the bottom of the sea which can also have developed only very recently, after the submerging of the Soenda shelf. Where sea currents pass through narrow straits they exercise a strong scouring influence on the bottom. Figure 23 shows these erosion gullies in Soenda Strait. We can see the result from the presence of deep erosion gullies everywhere that such narrow passages occur.

It is quite conceivable that, during the rising of the sea-level, low parts of the land which had been encroached upon by stronger erosion on a lowered erosion basis during a large part of the Pleistocene made a sea connection between the Java Sea and the Indian Ocean possible.

This possibility is quite independent of the speculative question whether or not Soenda Strait corresponds with the situation of a transverse fault. In any case there is no reason to suppose that such faults exist between Java and Bali, or Bali and Lombok, *et cetera*. Obviously, we must remember, for these straits also, the possibility of the origin mentioned.

If the level of the sea was, during the Pleistocene, some hundred meters lower, important alterations must have occurred in other places as well. The bathymetric chart shows, for instance, that a connection between Sumatra and the series of islands west of Sumatra during that period must be taken into account. In the same way the

[27] M. Gignoux, *Géologie stratigraphique* (1936).

Arafoera Sea must have changed into an area of land connecting Australia with New Guinea. The available charts do not permit a reconstruction of contingent drowned rivers on this so-called Sahoel shelf. The shallow and narrow straits of the Aroe Islands are, however, generally supposed to be fragments of original river beds. It is probable that the narrow sea connections between Bato Daka, Togian, and Talatakoh (in the Togian Islands near Northern Celebes) must be considered to have had the same origin.

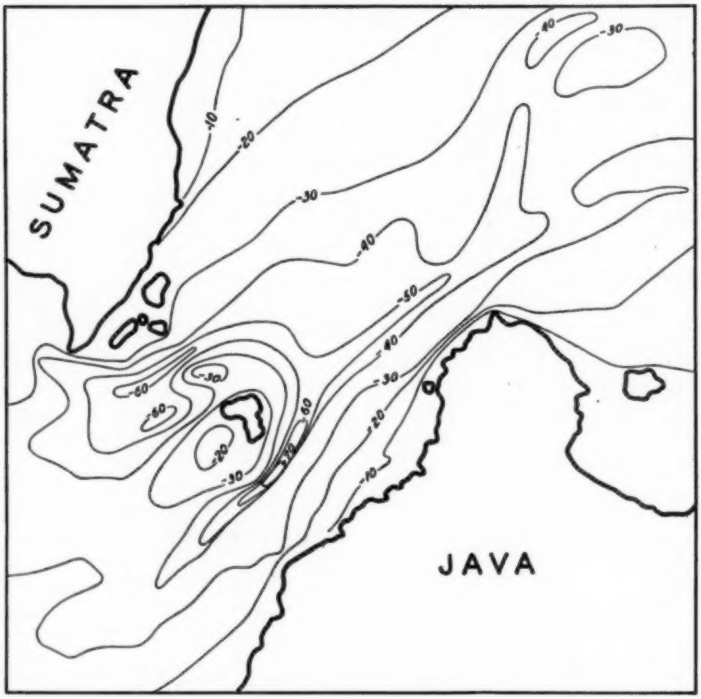


FIG. 23.—Isobaths in Sunda Straits. Depths in fathoms of 1.8 meters.

For the sake of completeness it must be mentioned, lastly, that the worldwide occurrence of a negative shifting of the coast line over an extent of several meters has led to Daly's hypothesis of a sinking of the sea-level during the latest geological times. As regards the East Indies, Van Tuyn gave a summary of this sinking in 1932. Kuenen paid much attention to this phenomenon in the eastern part of our archipelago (1933).

Chapter IV. Continuation of the East Indian Zones Outside the Region of the Archipelago

From the preceding discussion it is evident that areas with clear mutual differences in geological history may be distinguished in the East Indian Archipelago. The successive paleogeographic maps have illustrated this, and it is clearly demonstrated in the different sections. If the two areas where an intensive Miocene folding occurred (Timor, Sec. 1, East Celebes, Sec. 2) are compared with the much less intensively folded Miocene area of Southern Sumatra (Sec. 7) and if Southern Java (Sec. 6) is compared with an area like the southwestern part of New Guinea's Bird's Head, where the Miocene was scarcely folded at all (Sec. 5), this becomes evident at once. Thus we might go on summarizing.

What I especially wish to give here in a final chapter is an answer to the question whether the zones that can be distinguished in the East Indies can be continued outside this area. For this purpose it is easiest to discuss a continuation of the East Indian zones into the Asiatic continent and especially into Burma.

In the western part of the archipelago three zones are particularly clear. From the northeast to the southwest, we find: (1) the pre-Tertiary folded area of Malaya, Riouw Archipelago, Banka, and Billiton; (2) the geosynclinal basins of Atcheen (Atjeh) and Central to Southern Sumatra, folded towards the end of the Pliocene; (3) the areas whose most recent folding occurs in the Miocene. This last zone comprises the western strip of Sumatra (the so-called Barisan geanticline) and the zone of islands west of Sumatra. Can these zones be continued into the Asiatic continent?

In 1934 a summarizing volume on the geology of Burma appeared, written by Dr. H. L. Chhibber,[28] wherein everything known concerning the structure of that region is systematically explained.

Physiographically, three different zones may be distinguished in Burma, that coincide with three areas which are geologically different as well (Fig. 24): (1) the area of the Shan plateau and southward up to Tenasserim; (2) the so-called Central belt of Burma; (3) the Arakan Yoma, bounded on the west by the basin of Assam.

1. The first consists of pre-Tertiary rocks intensely folded with a north-south trend. The latest folded rocks belong to the Cretaceous (Laramide folding). During the entire Tertiary this area consisted of land. We find the continuation of this Tertiary land in Malaya, Riouw Archipelago, Banka, Billiton, continuing to Borneo. In discussing the pre-Tertiary history of the East Indies, we saw that in Malaya, *et*

[28] H. L. Chhibber, *The Geology of Burma* (1934).

cetera, folding occurred earlier (lower early Cimmerian at the end of the Triassic), and not later, as in the Shan plateau.

The Eastern zone of Burma is farther west towards the Central belt, bounded by a fault which in the landscape is to be seen as a morphologically very fine fault scarp.

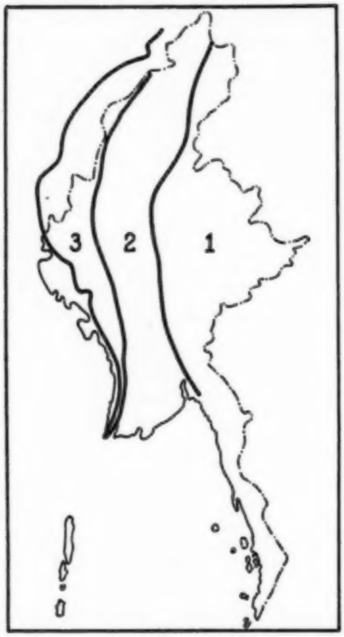


FIG. 24.—Physiographic and geological divisions of Burma. (After Chhibber.)

2. The Central belt is also called "the basin of the Burmese Gulf." It is a Tertiary basin of strong subsidence and intensive sedimentation: a geosyncline of absolutely the same type as the well known geosynclinal basins of Sumatra, Northern Java, *et cetera*.

The thickness of the Tertiary sediments is maximally approximately 13,000 meters. These sediments come from the east (Shan plateau), the west (Arakan Yoma, which was above sea-level during the Tertiary) and the north, where in the extreme north the Proto-Irrawaddy River debouched. The result is that the facies of the Tertiary sediments changes from south (predominantly marine sand-

stones, shales, and limestones) to north (terrestrial fluviatile and deltaic deposits). Consequently the facies never points to a greater depth than a maximum of 200 fathoms; so maximally it is neritic-to-hemipelagic, as Cotter pointed out. In this regard, too, the area is in agreement with the geosynclinal basins of the East Indies. The mechanism of the subsidence agrees. Sometimes the rate of subsidence kept pace with the rate of sedimentation, but sometimes it was greater, sometimes smaller. The same movements that have been reconstructed by Rutten, for example, for the basins of Atjeh and Central Southern Sumatra, from the thickness and facies of the sediments, have been found in Burma. The marine fauna, too, shows striking points of resemblance with that of the East Indian Tertiary. Further it is an important oil-bearing region like the Indian geosynclines, which shows its relationship not only by the similarity of the sediments but also by the analogous type of intensity of folding. Also, the period of folding is the same (end of Tertiary or beginning of Pleistocene). And last of all, the present Gulf of Martaban is, according to Cotter, a recent remnant of the Tertiary geosynclinal area, as in the East Indies the basin of Atjeh is clearly continued below the sea, and the basin of Java into Madoera Strait.

3. The Arakan Yoma (with the Naga and Manipoer hills) is an area of folding wherein no Paleozoic has been found, but Mesozoic has (Triassic and Cretaceous, no certain Jurassic fossils). The area was folded towards the end of the Cretaceous (Laramie phase) and formed a barrier between the Burma geosyncline on the one side and the Gulf of Assam on the other, in the Eocene. During the Tertiary it remained "an ever-rising geanticline," an uplift, wherein three phases of crustal movement can be distinguished: one towards the end of the Mesozoic, a second in mid-Miocene, and a third in post-Pliocene. The question is now: what is the corresponding zone in the East Indian Archipelago? Chhibber writes that it "continues southwards through the Andaman and Nicobar islands to Sumatra and Java."

Theoretically it is possible that the western part of Sumatra (the so-called Barisan geanticline), as well as the series of islands west of Sumatra, did indeed during the Tertiary form one zone, which must be considered as the continuation of the Arakan Yoma.

The origin of two "geanticlines" (Barisan and the series of islands west of Sumatra) and their separation by a fairly deep sea basin should then have happened during the most recent times, in the post-Pliocene (simultaneously with the latest phase in the elevation of the Arakan Yoma). This representation stands a good chance of agreeing

with reality. We saw in the foregoing pages that the time of the Tertiary periods of folding of both areas (Sumatra and the series of islands farther west) agree. The occurrence of a Pliocene unconformity (Southern Sumatra, Western Java, Timor) can not be called an important difference with regard to the Arakan Yoma; for, in the East Indian Archipelago, too, it seems that no Pliocene transgression occurred across large areas (Southeast Java). Consequently Chhibber's idea seems to me more probable than the second possibility, namely, that the continuation of the Arakan Yoma can be found only in the series of islands west of Sumatra. Theoretically a third possibility exists, namely, that the Arakan Yoma has its equivalent in the Barisan of Sumatra and that the "geanticline" of the series of islands west of Sumatra either ends before the coast of Burma is reached or is continued in Arakan and Assam without, however, being known as such, perhaps even without being visible on the surface.

Of the three theoretical possibilities mentioned, the second seems the least probable, for it requires the supposition that Burma lacks an equivalent of the Barisan of Sumatra, while during the Tertiary the Arakan Yoma played an entirely analogous part as an area of denudation with regard to the geosyncline of Central Burma, as the area of the "Barisan" did with regard to the Tertiary basins of subsidence and sedimentation of Sumatra.

Chhibber distinguishes five different eruptive zones in Burma. The recent volcanic strip that can be followed from Central Burma by way of the Narcondam and Barren islands to Sabang and then by way of Sumatra and Java to the lesser Soenda Islands, is of especial importance to us.

Moreover, the strip of serpentinized peridotites is of interest to us. According to Chhibber it can be traced "from Java and Sumatra through the Andaman and Nicobar Islands in the south, to the frontiers of Burma and Assam in the north." He considers this serpentine belt as having originated during the late Cretaceous-early Eocene movement. As we mentioned before, the ultra-basic rocks in the zone Timor-East Celebes seem to be of Triassic age.

For lack of sufficient detailed knowledge, it is not yet possible to follow the East Indian zones beyond Burma to Western Asia and Europe. The few facts that are known, however, justify the conjecture that this will, in the future, probably be possible.

For in the Himalaya and the Karakorum chains of mountains, also, several phases of folding have been distinguished that do not all occur in the entire chain of mountains, but, on the contrary, occur in special zones only. This is made clear in a recent publication, by

De Terra[29] who, on the ground of his own field researches, gives a summary of these phases of folding. He states that after an intensive folding towards the end of the Cretaceous, "the northern sector apparently continued to be land, the southern or Himalaya part resumed its geosynclinal evolution." During the Tertiary, the remaining geosyncline underwent a strong folding after the mid-Eocene and before the Lower Miocene. And perhaps movements occurred simultaneously with the Miocene folding in the East Indies. For De Terra continues: "This orogeny may have continued to the end of the Burdigalian epoch (Lower Miocene), or at least it may have been locally revived at that time . . ." After this folding, "possibly divided into an Oligocene and a Lower Miocene sub-phase," the entire Himalayan area remained above sea-level. In the middle of the Tertiary a so-called fore-deep was formed along the southern edge of the Himalaya wherein the Siwalik beds, many thousand meters thick, erosion products of the Himalaya, which can be compared with the Alpine molasse, were deposited. These Siwalik layers were folded during the Pleistocene. At the same time the southern chains of the Himalaya were overthrust to the south and "the Karakorum and adjoining regions suffered a broader uplift."

The times of the several movements and their restriction to certain areas remind one of conditions in the East Indies. On the other hand, De Terra pointed out some resemblances with the Alps.

As long as the geological history of the Philippines, and, incidentally, that of Halmaheira and the northern arm of Celebes, is as little known as it is now, it is impossible to make a detailed comparison between the geology of the East Indies and that of the islands on the north.

Lastly, we may briefly point to the fact that the Miocene area of folding east of New Guinea extends probably into the group of the Fiji Islands.[30]

Miocene folding has been established in the New Hebrides, where, according to Mawson, the folding is directed towards the "foreland," New Caledonia.[31] In the same way we recognize steeply dipping Mio-

[29] De Terra, "Himalayan and Alpine Orogenies," *Report XVI Internat. Geol. Congress, 1933,* Vol. 2, ed. 1936.

[30] From the interesting monograph on the island Viti Levu by H. S. Ladd (*Bernice P. Bishop Museum Bull. 119,* 1934), it appears *a.o.* that Miocene occurs unconformably (Tertiary *e*). Movements in the Upper Tertiary considered by Ladd to be local disturbances (*op. cit.*, p. 54) were regarded as an important period of folding by Brock, a former investigator of this island.

An intensive folding and a long denudation had occurred earlier on Viti Levu, namely, before the Paleogene.

[31] Extensive submarine tuffaceous beds were accumulating above the folded Miocene series (D. Mawson, *Proc. Linnean Soc. New South Wales,* 30 (1905), p. 471).

cene sediments, unconformably covered by faintly undulating Pliocene in New Britain.[32] On the other hand, southward from the islands just mentioned and in the direction of Australia, increasingly old zones of folding are found. In New Caledonia the most recent folding occurs after the Eocene,[33] whereas the principal folding of New Zealand appears to be even older, namely, post-Jurassic, the so-called late Cimmerian folding.[34]

[32] W. N. Benson, "The Structural Features of the Margin of Australasia," *Trans. New Zealand Institute*, Vol. 55 (1924), p. 120.

[33] Old phases of folding occur in New Caledonia in the Paleozoic, afterwards (Cimmerian) post-Triassic and before the transgression of the Portlandian, after that (Laramide) post-Cretaceous and before the transgression of the Lutetian, and finally a last great folding after the Eocene. (After Piroutet, see O. Wilckens, *Geol. Rundschau*, 16, 1925.)

[34] A. Born, "Der Geologische Aufbau der Erde," in *Handbuch der Geophysik*, II, 2 (1932), p. 763 and Fig. 306. See also O. Wilckens, *Geol. Rundschau*, 8 (1917), pp. 143–61

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RECENT OIL DISCOVERIES IN SOUTHEASTERN ILLINOIS[1]

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ABSTRACT

The new fields of southeastern Illinois are within 30 miles of the old fields of Crawford and Lawrence counties. Discoveries have been made in Wayne, Clay, and Richland counties in a belt about 20 miles long.

Studies of information furnished by old shallow tests, followed by torsion-balance and reflection-seismograph surveys, led to the drilling of the discovery wells. The anticlinal ridge on which the new fields are developing is an extension southwest of the Oakland anticline of Edgar and Clark counties. Oil is produced from the McClosky, an oölitic "pay" in the St. Genevieve limestone of Lower Mississippian age. The McClosky is the principal producing horizon in the south end of the old fields of Lawrence County.

Two sands above the St. Genevieve in the lower Chester have shown oil, but since all wells so far have been drilled to the McClosky, these sands have not been tested to any extent.

INTRODUCTION

New oil fields are under development 30 miles west of the old southeastern Illinois fields. The discovery well was near Cisne in Wayne County; the second near Clay City in Clay County. These discoveries, which were completed in March, 1937, were 12 miles apart. The Noble field, discovered in July, is 6 miles northeast of Clay City. Recently discoveries have been made 2 miles northeast of Noble. From Cisne to the new area northeast of Noble oil has been found in five separate areas in a belt more than 20 miles long. The old fields of southeastern Illinois, which extend for 60 miles across Clark, Crawford, and Lawrence counties, have had continuous development for more than 30 years. They have produced 400,000,000 barrels of oil. The general geological conditions affecting southeastern Illinois have been known for more than 100 years.

Though the new area appears large and boom conditions now prevail, we should not lose sight of the fact that these are typical Illinois fields. In the old fields of Illinois, oil has been produced from

[1] Read before the mid-year meeting of the Association at Pittsburgh, October 16, 1937.

[2] Chief geologist, The Pure Oil Company, 35 East Wacker Drive.

Lynn K. Lee, division geologist of The Pure Oil Company at Olney, Illinois, furnished information on wells recently drilled. H. N. Coryell and J. G. Mitchell prepared the correlation chart used as Figure 2. All operators in the southeastern Illinois fields know the work of Blatchley published as *Bulletin 22* of the Illinois Geological Survey in 1913, and *Bulletin 54* by Mylius in 1927. The structural trends and old fields shown in Figure 1 were taken from *Bulletin 54*. Many publications of the Illinois Geological Survey have in recent years called attention to the large unexplored basin area of southern Illinois.

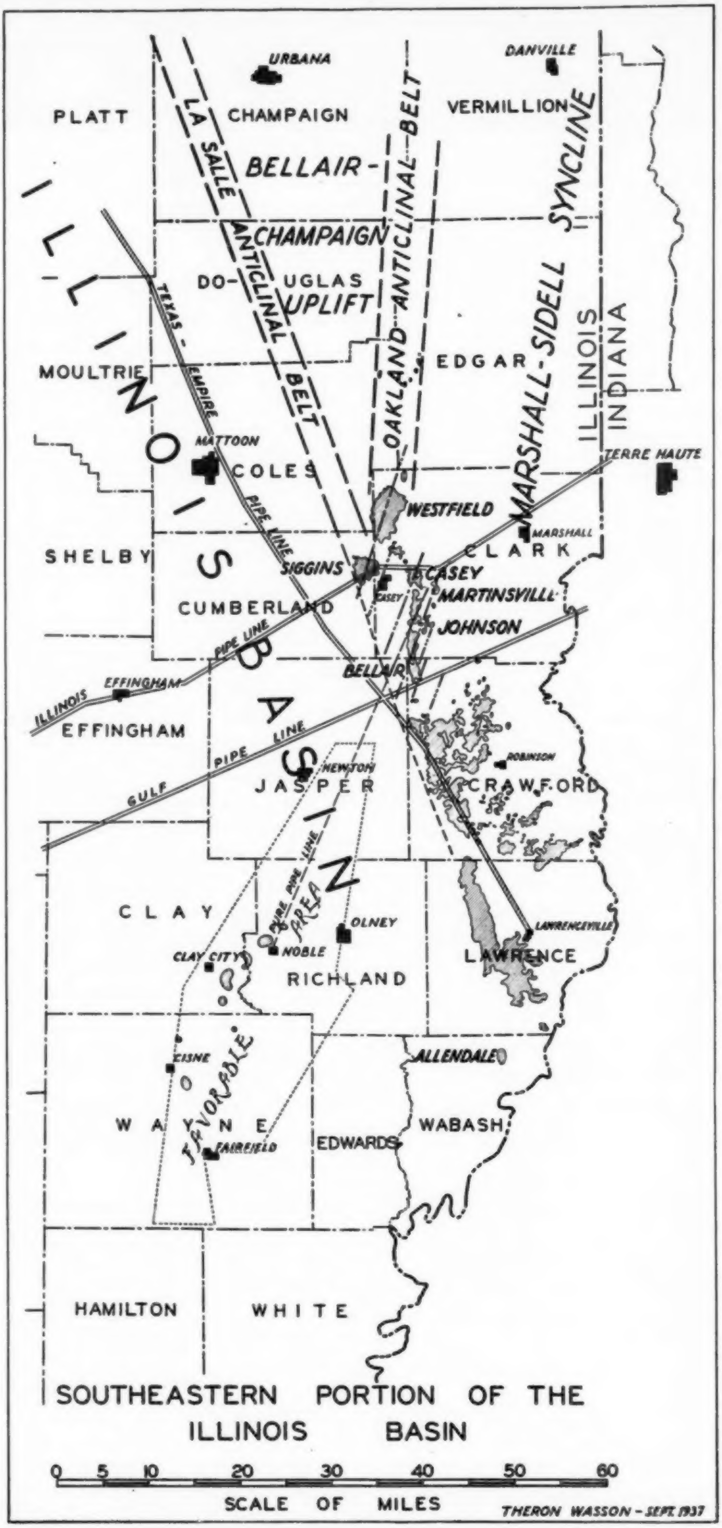
URBANA
DANVILLE
PLATT
CHAMPAIGN
VERMILLION
LA SALLE ANTICLINAL BELT
BELLAIR-CHAMPAIGN UPLIFT
OAKLAND ANTICLINAL BELT
MARSHALL-SIDELL SYNCLINE
ILLINOIS BASIN
DO- UGLAS
MOULTRIE
EDGAR
ILLINOIS
INDIANA
TEXAS-EMPIRE PIPE LINE
MATTOON
COLES
TERRE HAUTE
WESTFIELD
MARSHALL
CLARK
SHELBY
SIGGINS
CASEY
MARTINSVILLE
JOHNSON
CUMBERLAND
ILLINOIS PIPE LINE
EFFINGHAM
BELLAIR
EFFINGHAM
GULF PIPE LINE
NEWTON
JASPER
ROBINSON
CRAWFORD
PURE PIPE LINE
FAVORABLE AREA
CLAY
OLNEY
CLAY CITY
NOBLE
RICHLAND
LAWRENCEVILLE
LAWRENCE
CISNE
ALLENDALE
WAYNE
FAIRFIELD
EDWARDS
WABASH
HAMILTON
WHITE
SOUTHEASTERN PORTION OF THE ILLINOIS BASIN
0 5 10 20 30 40 50 60
SCALE OF MILES
THERON WASSON - SEPT. 1937

FIG. 1

small long-lived pumping wells. The same will be true in the new fields, 30 miles away.

Production is coming from the McClosky, an oölitic limestone of the St. Genevieve, which is well known in the fields of Lawrence County. The new development has gone far enough to demonstrate that dry holes will be found offsetting big wells. From experience in the old fields we know the flowing life will be short. Decline will be rapid in the first months of production and the area as a whole will make its oil from wells that are on the beam or pumping from a central power.

AREA

The area under discussion, which includes parts of Wayne, Clay, Richland, Jasper, and adjacent counties, is 60 miles long and 30 miles wide. It is a flat farming region, rather thickly settled by people whose pioneer ancestors came into the region from Kentucky and Virginia. This territory has an elevation of about 500 feet above the sea. Drainage is into the Wabash Valley by streams flowing southeastward. From south to north across the area the Little Wabash and the Embarrass are the principal streams. The Baltimore and Ohio Railroad runs east and west, and the Illinois Central north and south through the area. The main towns from south to north are Fairfield, Olney, and Newton. The city of St. Louis is 100 miles west and Chicago 250 miles north of the first discoveries.

As shown in Figure 1, the Cisne field is in north-central Wayne County; the Clay City field in southeastern Clay County; the Noble field and its northeast extension in western Richland County.

GENERAL GEOLOGY

Geologists familiar with this territory know that the relatively flat plain has a surface cover of glacial drift about 50 feet thick, consisting of unconsolidated sand and clay left after the retreat of the ice sheets which once covered it. This mantle of glacial material has covered the bed rock to such an extent that it is impossible to do any detailed surface mapping. The old southeastern Illinois fields are on the LaSalle anticline, which has been outlined by drilling in the southeastern counties and by studies of rocks exposed on the surface near LaSalle. Early oil explorers venturing west from the fields of Crawford and Lawrence counties soon lost interest after drilling into salt water at depths comparable with those at which they found oil in the old fields. Very few tests went deeper than 2,000 feet. Both Blatchley and Mylius in mapping the subsurface conditions in the

old fields showed a pronounced west dip, and other publications of the State Survey have outlined the LaSalle anticline in considerable detail, calling attention to the steep dip on the west side and the rather flat east side.

EXPLORATION FOR STRUCTURE

Following the discovery of oil in Michigan in 1927, the geological department of The Pure Oil Company became interested in the Illinois basin and for the first time became acquainted with the staff of the Illinois Geological Survey. As a preliminary study, a cross section was prepared from Lawrenceville to St. Louis. The published logs of old wells were used for this section. It showed a disturbance in the area between Flora and Olney. This suggested structural feature was not given great weight because there was a chance for error in the logs. It was a clue, however, which led to the reconnaissance torsion-balance survey made in 1930. This work, which started at the Indiana line and crossed a part of the old fields, indicated a gravitational disturbance west of Olney, similar to that found on the south end of the LaSalle anticline. The success of the reflection seismograph in Oklahoma and Texas led to a survey by that method in Illinois during 1935 and 1936. The seismograph work checked the existence of a structural disturbance extending across Wayne, Richland, and Jasper counties. Drilling has so far confirmed the geophysical work. The structural feature along which the new pools are located appears to be an extension southwestward from the Oakland anticline. It has an axial trend parallel with the cross folds outlined by Mylius.[3] The DuQuoin anticline and other structures of southern Illinois have similar northeast-southwest trends.

DEVELOPMENT

A block of 250,000 acres taken during the month of April, 1936, led to the drilling of a first test near Cisne in Wayne County, and the second test near Clay City in Clay County, 12 miles north. These tests discovered oil in sands of the basal Chester. Deeper drilling at Clay City on the Bunyan Travis farm discovered the first production in the McClosky sand of the St. Genevieve. This well's initial production was 2,640 barrels per day from a depth of 2,964 feet. More recently, drilling has been extended northeastward 6–8 miles to the Noble area, Richland County.

The principal production so far has been from the McClosky pay

[3] L. A. Mylius, "Oil and Gas in East-Central Illinois," *Illinois Geol. Survey Bull.* 54 (1928).

horizon found in the top of the St. Genevieve of Mississippian age. It is one of the pay horizons in the south end of the old fields of Lawrence County, where it was first discovered on the McClosky farm in Sec. 25, Dennison Township. The McClosky is oölitic limestone of varying porosity dependent on the condition of the oölites. Wells which make big initial production are in oölitic layers which are soft and porous. These porous spots change within short distances into areas of dense, tightly cemented oölites. The thickness of the oil-saturated section varies from a few feet to 10 or 15 feet in the best wells. In the Clay City and Noble areas the McClosky is found at 2,950 feet. At Cisne it is at 3,070 feet. The greatest development to date has been in the Clay City area of Clay County where more than 60 wells have been drilled to the McClosky or are now close to it. The field at Noble, including the northeast extension, has 15 or 20 wells in or close to the McClosky. The Bradley area near Cisne, where so far the McClosky has shown little porosity, has three wells. These are producing from the Bradley sand and the McClosky. So far, the objective of all wells since the discovery of oil in the Bunyan Travis No. 1 has been the McClosky. Many wells in the Clay City area have been drilled through the McClosky "pay" without finding water. Some tests on the west flank have reported salt water, but little information has been developed in regard to possible water levels. Due to the lensing character of the porous streaks, water levels will probably be poorly defined.

Acid treatment is common practice and results in general are favorable, as the oölitic McClosky is easily dissolved by acid. Acid, however, can not make a producer out of a dry hole.

The first wells in the Cisne and Clay City areas were drilled with standard tools. The Bradley test at Cisne was spudded November 3, 1936. It was completed in the Bradley sand of the lower Chester on April 3, 1937. Information obtained by the first cable-tool tests made it possible to use Mid-Continent rotary equipment, with resultant increased speed and a great reduction in drilling cost. Wells are now drilled into the McClosky in less than 3 weeks. Good cores are obtained of the pay horizons.

Schlumberger electrical logs have been run in several key wells throughout the area and this method of logging will probably be of assistance in correlating beds drilled by the rotary but not cored.

SECTION DRILLED

Except for greater depths and increased thickness, the section drilled in the new area is similar to that in the south end of the old

field. Starting with the base of the section, which is the St. Genevieve, the formations so far drilled are as follows.

St. Genevieve formation.—The McClosky in the Clay City and Noble areas is found at a depth of 2,950 feet, which is approximately 50 feet below the top of the St. Genevieve limestone. The "pay" ranges up to 15 feet in thickness. One well in the Clay City area has been drilled through the St. Genevieve, showing it to have a thickness of 230 feet. In Lawrence County, the McClosky sand of the St. Genevieve is found at a depth of 1,600–1,800 feet. Published records show that the thickness of "pay" and type of porosity varied from one well to another. Some of these wells had high initial production, but they declined rapidly. Their production has been made from a great many pumping wells.

Chester formation.—In the Cisne and Clay City areas the Chester is 1,000 feet thick, and sands in the basal part are productive though sands of the Upper Chester contain salt water. The productive sands appear to be lenses, and although production may be spotted, they will add considerably to the total production of the area, but so far have not been tested sufficiently to make estimates of their possibilities. The Bradley sand in the Cisne area is at the base of the Chester, and the Weiler sand of the Clay City area is about 150 feet above the Bradley. These have not been correlated with sands in the old field but are referred to by operators as the Bradley and Weiler sands.

Study of the Chester section in wells so far drilled from Cisne to Noble shows very strikingly the marked unconformity at the base of the Pennsylvanian. In the Cisne area a nearly complete section of Chester is found, though at Noble, 18 miles north, upper Chester beds are missing, having been eroded in pre-Pennsylvanian time. This same condition exists along the LaSalle anticline from Lawrence County northward, where the Chester had a thickness of 300–500 feet and contains several producing sands.

The unconformity at the base of the Chester is not so apparent. There is a constant interval from any well defined limestone in the Chester to the top of the St. Genevieve, indicating that no angular unconformity is evident. Above the St. Genevieve, however, there appears to be a weathered zone about 80 feet thick which suggests a widespread interval of erosion. Further drilling along the new structure will develop the details necessary to show the relations of the St. Genevieve to the overlying beds.

Subsurface work done so far indicates that the Chester may be divided into zones based on the content of micro-fossils. These zones

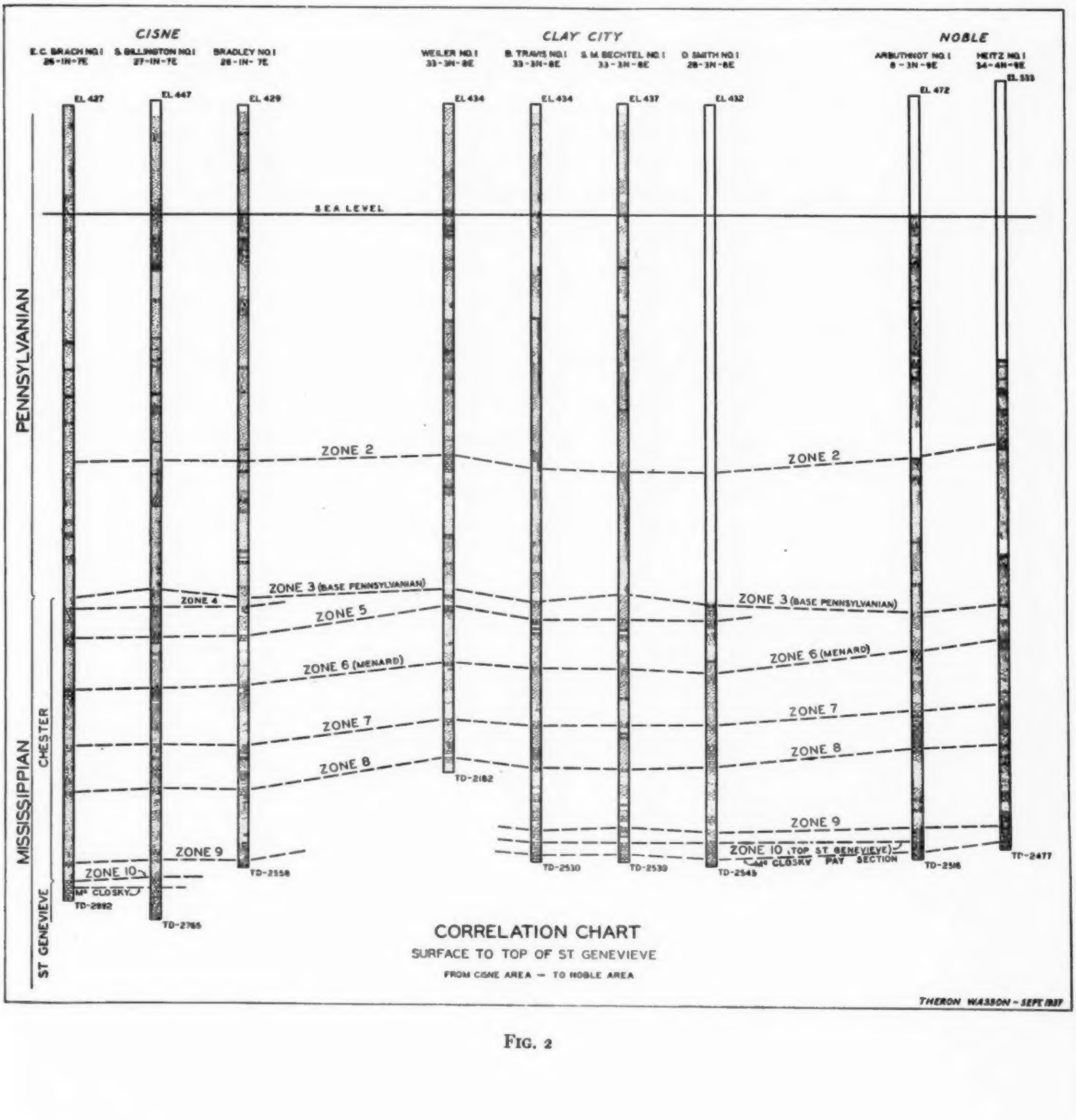
CISNE
E. C. BRACH NO. 1
S. BILLINGTON NO. 1
BRADLEY NO. 1
CLAY CITY
WEILER NO. 1
B. TRAVIS NO. 1
S. M. BECHTEL NO. 1
D. SMITH NO. 1
NOBLE
ARBUTHNOT NO. 1
HEITZ NO. 1
EL 427
EL 447
EL 429
EL 434
EL 434
EL 437
EL 432
EL 472
SEA LEVEL
PENNSYLVANIAN
MISSISSIPPIAN
CHESTER
ST GENEVIEVE
ZONE 2
ZONE 2
ZONE 3 (BASE PENNSYLVANIAN)
ZONE 3 (BASE PENNSYLVANIAN)
ZONE 4
ZONE 5
ZONE 6 (MENARD)
ZONE 6 (MENARD)
ZONE 7
ZONE 7
ZONE 8
ZONE 8
ZONE 9
ZONE 9
ZONE 10
Mc CLOSKY
ZONE 10 (TOP ST GENEVIEVE)
Mc CLOSKY PAY SECTION
TD-2182
TD-2558
TD-2530
TD-2530
TD-2545
TD-2516
TD-2477
TD-2765
CORRELATION CHART
SURFACE TO TOP OF ST GENEVIEVE
FROM CISNE AREA — TO NOBLE AREA
THERON WASSON - SEPT 1937

FIG. 2

conform fairly well with the subdivisions of the Chester established by Stuart Weller.[4] These relations are shown in the cross section of Figure 2.

Pennsylvanian formation.—So far the 2,000 feet of this formation drilled in the new area has shown only salt water in thick sand bodies. It is possible that productive sands similar to the old fields may be found on the north end of the structure in Richland and Jasper counties where the Pennsylvanian is not so thick. The old fields produce from several shallow sands in the Pennsylvanian.

DEEPER DRILLING

In Illinois and Indiana oil is produced from rocks older than the St. Genevieve, hence it is natural to speculate about the deeper possibilities in the new area. In western Indiana oil is found in Devonian limestones and dolomites. In the old Illinois fields, oil is produced from the Trenton. The St. Peter probably offers little possibility as it has not produced east of the Mississippi River. In a new area where a thick sedimentary section exists, there is the possibility of unknown and unexpected producing horizons. It will require drilling to a depth of 7,000 feet to answer these questions.

[4] Stuart Weller, "Geology of Hardin County, Illinois," *Illinois Geol. Survey Bull. 41* (1920).

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THE MEDINA AND THE TRENTON OF WESTERN NEW YORK[1]

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ABSTRACT

The Medina (Silurian) and the Trenton (Ordovician) formations of New York are well known members of the Lower Paleozoic system. Both have their typical outcrops in New York state and both are present as concealed formations with a generally southern dip throughout almost all the western part of the state. Folds and faulting are practically absent. Two divisions of the Medina are recognized, the upper, known as the Albion sandstone, being the source of most of the Medina gas. The most prolific Medina fields are in the counties bordering Lake Erie. The fields are slow yielding of their gas and have a long life.

The Trenton formation is predominantly a limestone but contains numerous beds of shale. Gas may be found at many horizons in a single well and large pockets of gas are commonly encountered. Small but persistent flows have been maintained in several shallow pools near the east end of Lake Ontario for more than 35 years. Deep tests of the Trenton in other parts of the state have failed to yield outstanding results.

INTRODUCTION

Both the Medina (Silurian) and the Trenton (Ordovician) formations are gas-bearing in New York state. Substantial fields which derive their gas from the Medina sandstone have been opened in western New York, whereas only limited production has been obtained from the few Trenton fields that have been developed. The earliest drilling operations were conducted with the hope of finding oil, but neither the Medina nor the Trenton has been found to be oil-bearing. In New York the Trenton lies only a few hundred feet above the pre-Cambrian rocks and is the lowest and oldest formation from which gas has been produced in substantial amounts.

In the following pages a brief account of the stratigraphy, together with the history and development of the Medina and Trenton gas fields, is given. As an example of a typical Trenton gas field the Pulaski is described in detail. For the map of the Pulaski gas field and for some of the data relating to the wells the writer is indebted to Tracy Gillette, Yonkers, New York.

MEDINA FORMATION

The Medina (Silurian) formation was named from the exposure at Medina, Orleans County, the term having been first used by

[1] Read before the Association at the Pittsburgh meeting, October 15, 1937. Published by permission of the director, New York State Museum.

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Vanuxem in 1840. In outcrop, the Medina forms a belt up to 10 miles in width all along the southern border of Lake Ontario. East of this lake and midway between it and the Black River valley, a large northern spur of the lower Medina occupies an extensive area on the Tug Hill plateau. Southeast from Lake Ontario the Medina thins to disappearance in Oneida County, where the lôwest Silurian formation is represented by the Oneida conglomerate, formerly classed as topmost Medina but now considered to be of Clinton age. The base of the Oneida here marks the Ordovician-Silurian boundary.

From its outcrop along Lake Ontario, the Medina extends as a concealed formation into Pennsylvania. The general dip is toward the south at a rate of 40–50 feet to the mile. In some sections there is a moderate flattening of the dip resulting in the formation of terraces on which certain gas fields are located, such as the Lancaster field in Erie County. In the Pavilion field, of Genesee County, drilling operations have indicated the presence of one or two small closed structures, but these have had little if any effect in localizing production in the field as a whole. From the Finger Lakes region south to the border of the state, the frequent reversal of dip as determined from the surface rocks is due to a series of northeast-southwest trending folds. These structures are the northernmost outliers of the Appalachian folds. In New York state they have their strongest development along the Pennsylvania border, whence they gradually diminish northward to fade out before the Lake Ontario region is reached. While productive of much gas from the Oriskany both in New York and Pennsylvania, these folds, or anticlines, have had but few tests to the Medina in New York, and in much of the region of larger folds the Medina lies too deep to encourage prospecting.

In the Niagara region the thickness of the Medina formation is a little more than 1,100 feet. This thickness is fairly well maintained in the surrounding counties, but gradually thins toward the east. In Onondaga County the thickness is about 700 feet, and from this point on the formation diminishes rapidly.

MEDINA SUBDIVISIONS

The Medina has two main subdivisions, the Albion sandstone for the relatively thin, but important, upper member and the Queenston shale for the thick lower member.

Albion sandstone.—In the Niagara Gorge, only a little more than 100 feet of the upper Queenston shale is exposed, whereas the entire thickness of the Albion can be seen in the gorge and conveniently studied along the cut of the New York Central Railroad at Niagara

Falls. The detailed section of the Albion at Niagara Falls as given by Kindle and Taylor[3] is as follows.

Albion sandstone	*Feet*
Sandstone, gray, massive, somewhat cross-bedded (Thorold sandstone member, the "gray band")	5
Sandstone, red and gray mottled, cross-bedded throughout but seen only on weathered faces	6
Sandstone, red, thin-bedded, and shale	20
Sandstone, gray, thick-bedded, at south merging into bed of immense concretionary masses and 210 feet farther south into shale	4
Shale, reddish, and thin-bedded sandstone	18
Sandstone, gray, thin-bedded, somewhat calcareous, with bryozoans in beds near base	5
Shale, bluish gray, argillaceous or sandy	19
Sandstone, white, cross-bedded (Whirlpool sandstone member)	22

The Albion sandstone member of the Medina is the most widespread gas-bearing formation in the state. At its top is a characteristic and well known sandstone about 5 feet thick. For more than 100 years this sandstone has been known as the Medina "Gray band." It has now been designated Thorold sandstone and, like the Oneida conglomerate with which it has been correlated, has been made the basal member of the Clinton, the position originally assigned it by Vanuxem. For purposes of convenience, the Thorold, or Gray band, has in this paper been retained in the Medina. The Thorold is in sharp contact with the Clinton limestones or shales above and affords the driller a signal that the Medina has been reached. Below the Thorold are beds of red and gray sandstones and shales with a total thickness of 75–100 feet as recorded in well records. They are usually logged as upper Red Medina and correspond in part to the Grimsby and Cataract of the Canadian sections. These beds are gas-bearing.

The Whirlpool sandstone, which is highly productive of gas, is the basal member of the Albion and generally marks the lower limit of the gas horizons of the Medina. The Whirlpool sandstone is named for the Whirlpool in the Niagara Gorge, from which it extends as a conspicuous formation along the walls of the gorge to its mouth at Lewiston. In the quarry at Lewiston, the Whirlpool consists of a coarse wave-marked white sandstone with cross-bedding a prominent feature. The individual sand grains are nearly pure white, and it is evident that the sandstone was formed in shallow water under the influence of wave and current action. No fossils have been found in the Whirlpool sandstone, but marine fossils are present in some of the higher beds of the Albion formation.

Queenston shale.—Below the Albion, with its contact sharply marked by the base of the Whirlpool sandstone, lies the Queenston member of the Medina, a formation nearly 1,000 feet thick and com-

[3] E. M. Kindle and Frank B. Taylor, "Niagara," *U. S. Geol. Survey Atlas, Folio 90* (1913), p. 6.

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posed of red and gray shales with some beds of reddish sandstone. The sharp contact between the Albion and the Queenston is not everywhere apparent. In the Genesee Gorge in Monroe County, where the upper beds of the Queenston and the entire thickness of the Albion beds are exposed, the Whirlpool sandstone has not been recognized and the Queenston grades up into the similarly colored beds of the Albion without any evidence of a time break. In the Baldwinsville field, of Onondaga County, where gas has been produced both from the Medina and the deeper Trenton, the upper part of the Medina is a white sandstone and is believed to belong to the Queenston rather than to the Albion member of the Medina. At Oswego, on the shore of Lake Ontario, an outcrop of the Oswego sandstone marks the base of the Medina and of the Silurian as well.

The Oswego sandstone was formerly included as part of the Medina, but on fairly conclusive lithologic and faunal evidence it appears to be closely related to the underlying Pulaski beds and is therefore regarded as the closing stage of the Ordovician rather than one introducing the Silurian. In the logs of many wells the Oswego has been designated as the lower White Medina, and it underlies the Medina throughout western New York with a thickness of 75 feet in the Erie County district, increasing to more than 200 feet in some of the eastern counties.

STRUCTURE

With the exception of a few structural terraces on which some of the Medina gas fields are located, there are no important anticlinal structures present in any of the gas areas so far developed. Lacking important structural control, the gas fields are dependent on porosity for their location. Much of the exploratory drilling has been carried on more or less blindly, and the fields have been developed much more slowly than would have been the case if reliable structural features were present. Lack of oil in the Medina has also served to slow up developments, but on the other hand the Medina sands are without any troublesome salt water. The porosity of the Medina sand is extremely variable and even well within the border of a field a good gas well may be found close to a poor one and a dry hole where least expected.

DISTRIBUTION OF FIELDS BY COUNTIES

Erie County.—Erie County has long been a producer of natural gas from the Medina sandstone. The original tests were made in the city of Buffalo in 1887 and their success resulted in the extension of operations in the vicinity of the city and as far north as Niagara County, where the depth to the Medina was less than 1,000 feet.

Exploration in the territory east and northeast of Buffalo soon followed. At present, gas fields are found in all parts of Erie County, with some developments still in progress. The combined area of the gas fields is larger than that of any other county. In depth, the wells range from about 700 feet in the northern part of the county to more than 3,000 feet on the southern border.

Chautauqua County.—The first test to the Medina in Chautauqua County was made in 1886, but active developments did not take place until 1903. The district that has been most productive is in the northern part in the vicinity of Dunkirk, Silver Creek, Forestville, Arkwright, and Fredonia. The fields are bordered on the west by Lake Erie and as a whole comprise an area of about 10 square miles. In depth the wells vary from 1,700 to 2,400 feet. They have exceptionally large initial production and the area has become one of the important producing districts of the state.

Cattaraugus County.—Gas pools are found in the northern part of Cattaraugus County, along the Erie County border, in the towns of Otto, Persia, and Perrysburg, where the Medina is reached at depths of about 3,000 feet. Initial production of some of the larger wells has been as much as 6 million cubic feet daily. Recently several wells have been drilled in the town of Leon, a few miles south of the Perrysburg field. The depth to the top of the Medina varies from 3,300 to 3,600 feet. According to reports one well had an initial flow of 3 million cubic feet of gas daily with a rock pressure of 1,370 pounds. Not all the wells have been successful in finding gas.

Genesee County.—The most important gas field in Genesee County is the Pavilion, discovered in 1906. The field comprises an area of about 35 square miles, over which more than 100 productive wells have been drilled. Most of the wells are in the town of Pavilion, with some in the town of Bethany on the west. The southern part of the field extends into Wyoming County, and on the east a few wells have been drilled in Livingston County. Some of the original wells yielded from 5 to 7 million cubic feet of gas a day with rock pressures in excess of 500 pounds. The wells vary from about 1,600 to more than 1,800 feet in depth. One test well in the Pavilion field reached a depth of 4,082 feet, the top of the Trenton being penetrated at 3,720 feet. Gas was found in the Medina, but not in the Trenton limestone. Another field in Genesee County is located in the towns of Darien and Pembroke and is known as the Corfu field. The field is old and of little importance at present.

Monroe County.—The Churchville field in the town of Riga is a small but persistent producer. It is the only pool in Monroe County, but is of special interest in that it lies but 7 miles south of the Medina

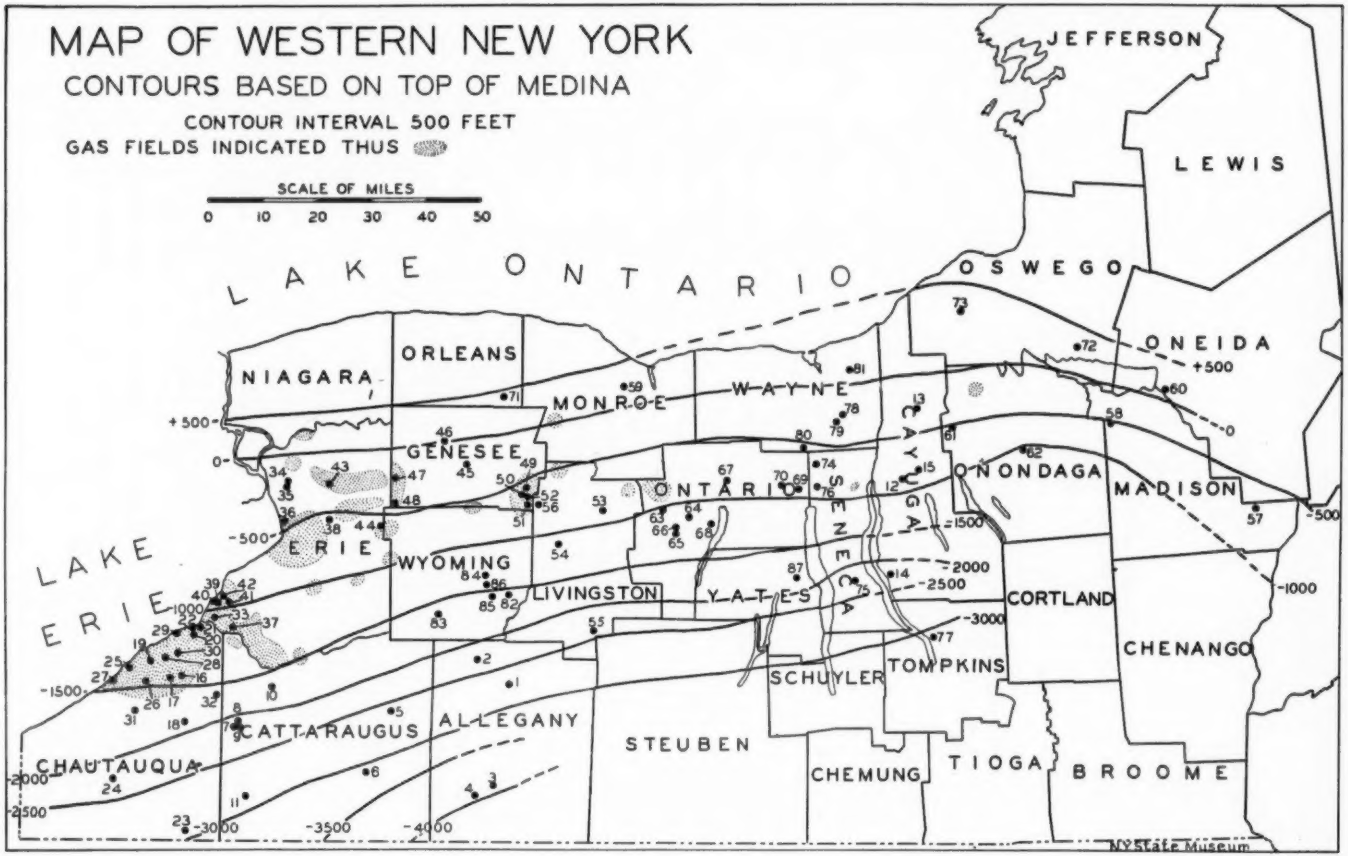

MAP OF WESTERN NEW YORK
CONTOURS BASED ON TOP OF MEDINA
CONTOUR INTERVAL 500 FEET
GAS FIELDS INDICATED THUS
SCALE OF MILES
0 10 20 30 40 50
LAKE ONTARIO
LAKE ERIE
JEFFERSON
LEWIS
OSWEGO
ONEIDA
NIAGARA
ORLEANS
MONROE
WAYNE
CAYUGA
ONONDAGA
MADISON
GENESEE
ONTARIO
SENECA
ERIE
WYOMING
LIVINGSTON
YATES
CORTLAND
CHENANGO
SCHUYLER
TOMPKINS
CHAUTAUQUA
CATTARAUGUS
ALLEGANY
STEUBEN
CHEMUNG
TIOGA
BROOME
NY State Museum

FIG. 1

TABLE I
WELL DATA FOR SUBSURFACE MAP OF MEDINA FORMATION

Map No.	County	Township	Name of Well	Elevation in Feet	Depth to Medina in Feet	Elev. Top Medina Referred to Sea-Level
1	Allegany	Allen	Bank of Angelica	2,006	4,804	−2,798
2		Hume	Connor	1,430	3,610	−2,180
3		Wirt	Cady	1,917	5,890	−3,973
4		Wirt	Gilbert	2,071	6,024	−3,953
5	Cattaraugus	Franklinville	Franklinville	1,644	4,478	−2,834
6		Humphrey	E. J. Hare No. 1	1,942	5,065	−3,123
7		Leon	Percy Curtis	1,344	3,431	−2,087
8		Leon	Garvey	1,641	3,688	−2,047
9		Leon	Clyde Greeley	1,344	3,439	−2,095
10		Otto	Skinner Hollow	1,375	3,067	−1,692
11		Randolph	Hotchkiss	1,740	4,595	−2,855
12	Cayuga	Aurelius	W. Baker	555	1,459	− 904
13		Cato	Silas Whitford	519	817	− 298
14		Ledyard	Mahaney	830	3,081	−2,251
15		Throop	Old Auburn	560	1,505	− 945
16	Chautauqua	Arkwright	C. H. Beebe	1,100	2,504	−1,404
17		Arkwright	Theiss	1,650	3,037	−1,387
18		Charlotte	Estee	2,040	3,875	−1,835
19		Dunkirk	Seybold No. 1	710	1,980	−1,270
20		Hanover	Barriss	740	1,922	−1,182
21		Hanover	Raymond Dubert	610	1,742	−1,132
22		Hanover	Silver Creek	610	1,900	−1,290
23		Kiantone	Weiss	1,244	4,194	−2,950
24		North Harmony	Randall	1,520	3,705	−2,185
25		Pomfret	Emma Hall	610	1,870	−1,260
26		Pomfret	Wilber No. 1	950	2,396	−1,446
27		Portland	C. W. Wenborne	640	1,978	−1,338
28		Sheridan	J. Merritt	780	2,055	−1,275
29		Sheridan	St. Columbans	590	1,680	−1,090
30		Sheridan	M. J. Tooke	820	2,094	−1,274
31		Stockton	L. C. Warren	1,320	2,944	−1,624
32		Villanova	Phillips	1,310	3,070	−1,760
33	Erie	Brant	Bemus Pierce	740	1,885	−1,145
34		Buffalo (City)	City Hospital No. 1	680	805	− 125
35		Buffalo (City)	City Hospital No. 2	680	775	− 95
36		Buffalo (City)	South Park	600	1,052	− 452
37		Collins	George Button	660	1,850	−1,190
38		Elma	Spring Brook	800	1,433	− 633
39		Evans	A. A. Carpenter No. 2	630	1,549	− 919
40		Evans	A. A. Carpenter No. 3	610	1,585	− 975
41		Evans	A. C. Davis	680	1,620	− 940
42		Evans	R. H. Davis	640	1,547	− 907
43		Lancaster	Depew	680	884	− 204
44		Marilla	No. 605	1,140	1,803	− 663

Map No.	County	Township	Name of Well	Elevation in Feet	Depth to Medina in Feet	Elev. Top Medina Referred to Sea-Level
45	Genesee	Batavia	Batavia (City)	889	1,100	− 211
46		Batavia	John Gibson	870	878	− 8
47		Darien	Wm. Edzold	870	1,075	− 205
48		Darien	Schaffer	1,019	1,446	− 427
49		Pavilion	Callan			− 532
50		Pavilion	Hutchinson			− 645
51		Pavilion	G. Johnston			− 700
52		Pavilion	J. Millikin			− 694
53	Livingston	Avon	Wadsworth	830	1,755	− 925
54		Leicester	Cuylerville			−1,157
55		Ossian	Gruschow	1,140	3,550	−2,410
56		York	York			− 729
57	Madison	Brookfield	Letts	1,2[illegible]	1,863	− 643
58		Sullivan	Chittenango	444	954	− 510
59	Monroe	Rochester (City)	Old Rochester	506	250	+ 256
60	Oneida	Verona	Ainsworth	400	260	+ 140
61	Onondaga	Elbridge	Ashby	425	937	− 512
62		Onondaga	Yenny	1,013	2,048	−1,035
63	Ontario	Bloomfield	Paul	885	1,938	−1,053
64		Bristol	Footer	910	2,035	−1,125
65		Bristol	Lynn Gladding	1,444	2,758	−1,314
66		Bristol	Rubenstein No. 2	1,297	2,615	−1,318
67		Canandaigua	Brown	663	1,402	− 739
68		Canandaigua	Munson	1,040	2,258	−1,218
69		Phelps	L. Lynch	519	1,470	− 951
70		Phelps	Peck	610	1,510	− 900
71	Orleans	Clarendon	Emilkampf	660	207	+ 453
72	Oswego	Constantia	Frank Parker	500	72	+ 428
73		Volney	Van Buren	320	18	+ 302
74	Seneca	Junius	F. Bump No. 2	502	1,208	− 706
75		Ovid	Carrie Chapman	879	3,106	−2,227
76		Waterloo	C. H. Mills	476	1,418	− 942
77	Tompkins	Lansing	Farkas	850	3,980	−3,130
78	Wayne	Galen	Ethel Arnold	461	760	− 299
79		Galen	Welch No. 1	413	760	− 347
80		Lyons	Alloway	420	980	− 560
81		Wolcott	Old Wolcott	317	230	+ 87
82	Wyoming	Castile	John Harding	1,515	3,105	−1,590
83		Eagle	John Anderson	1,820	3,611	−1,791
84		Gainesville	Cummings No. 1	1,400	2,730	−1,330
85		Gainesville	Randolph	1,600	3,205	−1,605
86		Gainesville	Stamp	1,640	3,005	−1,365
87	Yates	Torrey	Louise Kipp	890	2,608	−1,718

outcrop. The gas comes from a horizon about 75 feet below the top of the Medina, which is reached at a depth of 480 feet. The Whirlpool sandstone can not be recognized at the outcrops in Monroe County, and apparently the gas occurs in a higher zone of the Albion sandstone.

Ontario County.—In the town of Bristol, Ontario County, is the site of the famous gas or "burning spring," visited and described by LaSalle in 1669.

Several small gas pools have been developed in this county, the main producing area being in the town of West Bloomfield adjacent to Livingston County, where the Medina is reached at depths of 1,800–2,000 feet. In this area, initial production varies from a few thousand feet to a million cubic feet a day. In other parts of the county, a few successful wells have been drilled, particularly in the towns of Bristol and Richmond.

Developments in Ontario County began about 1895 and the production of gas has been well sustained. The fields are the most easterly in the state, where Medina gas production has been maintained over a period of years. The group of wells in Seneca County, which produced from both the Medina and the Clinton, have long since been abandoned.

Livingston and Wyoming counties.—Only very small scattering pools have been found in these counties, which are of little importance at present. A small production is obtained from pools lying largely in adjacent counties.

CONCLUSIONS

The Medina gas fields are not extraordinary in that they can be compared in pressure or yield with those of the great natural gas districts of the country. A few wells may have initial flows of as much as 8 million cubic feet a day, but for the most part, the flows are only moderate—a few hundred thousand cubic feet ordinarily being the upper limit. The fields have proved profitable, however, by reason of their long life and favorable conditions for transporting and marketing the gas.

During recent years the total annual production of natural gas in New York state has averaged about 7 billion cubic feet. Of this amount, it has been estimated that perhaps half was produced from the Medina sandstone. For several years previous to 1933 about half the natural gas consumed in the state was imported from Pennsylvania, most of it being used in the Erie County district. Since the discovery of gas a few years ago in the Oriskany sandstone, importa-

tion has nearly doubled, most of the increase going to communities outside of the Medina gas districts. It is true, to be sure, that these newly discovered supplies of gas from the Oriskany in both New York and Pennsylvania will undoubtedly slow up development in some of the Medina fields, at least so long as Oriskany gas can be supplied at the present low rates. To offset the situation, recently constructed pipe lines will serve as an incentive for further drilling, especially in the deeper territory, since they will afford a ready means of transporting any newly discovered gas to market.

TRENTON FORMATION

The type section for the Trenton formation is in New York state at Trenton Falls, on West Canada Creek along the boundary of Oneida and Herkimer counties. The name "Trenton" as a geologic term has been in use since 1838. At its type section, the Trenton is predominantly a limestone, and is usually described as such, although in some localities the limestone layers alternate with those of shale. East from the type locality, and as developed in the Mohawk Valley, the upper limestone gradually changes horizontally to thick beds of shale and sandstone which have been named the Canajoharie shale for the lower, and the Schenectady shales and sandstones for the upper member.

As the name is used in the natural gas fields, the Trenton includes at its base the limestones of the Black River group. Thus defined, the Trenton limestone consists of an assemblage of calcareous beds that lie just below the Utica shale of Cincinnatian age and extend downward to the top of the Little Falls dolomite, which is of Cambrian age. The Trenton limestone is abundantly fossiliferous, and it is not uncommon to find typical fossils among the well samples.

From the type section of the Trenton along the southwestern border of the Adirondacks, the outcrop takes a northwesterly direction into the Black River valley, where there are excellent exposures in the vicinity of Watertown. From here it continues as a broad belt extending west to the St. Lawrence River and Lake Ontario. The Trenton does not crop out at any locality in western New York, but is exposed in Canada north of the shore of Lake Ontario, beneath which the beds extend south and enter the state as a concealed formation approximately 1,500 feet below the lake level. In this region the strata have a southerly dip of 40–50 feet a mile, whereas the land surface gradually rises from Lake Ontario (elevation, 246 feet) to the top of the Allegheny plateau, with varying elevations up to 2,000 feet along the southern border of the state. These factors have

had their influence in restricting Trenton drilling to the counties bordering Lake Ontario and Lake Erie, with only a few tests in the central area of the state where one or two of the wells drilled reached a depth of more than 6,000 feet without finding gas. In thickness, the Trenton in the western counties ranges from about 700 to nearly 800 feet. At the east in Oswego County the thickness is 600 feet and only 400 feet in Oneida County.

In the western counties a sufficient number of wells have not been drilled to determine the presence of any structures in the Trenton favorable to the accumulation of gas. Neither surface indications nor information gained from the drilling of the higher formations are likely to prove of value in locating any deep Trenton gas fields.

Commercial gas from the Trenton is produced only in the counties of Oswego, Onondaga, Oneida, and Lewis. The total number of Trenton wells drilled in the state is given herewith.

Cayuga	2	Niagara	5
Chautauqua	1	Oneida	50
Erie	7	Onondaga	66
Genesee	2	Orleans	4
Herkimer	1	Oswego	165
Jefferson	4	Seneca	2
Lewis	10	Tompkins	1
Madison	2	Wayne	10
Monroe	2	Total	334

TRENTON GAS FIELDS BY COUNTIES

Since the production of Trenton gas is limited to Oswego County and to the counties that border on it—geological features, occurrences of gas and field developments being comparable—the Pulaski field will be described in some detail as a type locality, after brief mention of outstanding facts in the other Trenton fields.

Onondaga County.—The Baldwinsville field is the most westerly field in which gas has been produced from the Trenton in commercial quantities. Development began in 1896, the field producing until 1932, when many of the wells were sold to property owners. During the period of its activity, the gas was used to supply the village of Baldwinsville.

Sixty wells were drilled in the field to depths of 2,100–2,500 feet. Some of the earlier wells yielded as much as 3 million cubic feet of gas daily, the highest rock pressure recorded being 1,450 pounds. The Baldwinsville wells also penetrated the higher Medina formation, from which small flows of gas were obtained.

Oneida County.—The first attempt to develop a gas field in the city of Rome was made 40 years ago. Eight wells were drilled, some of

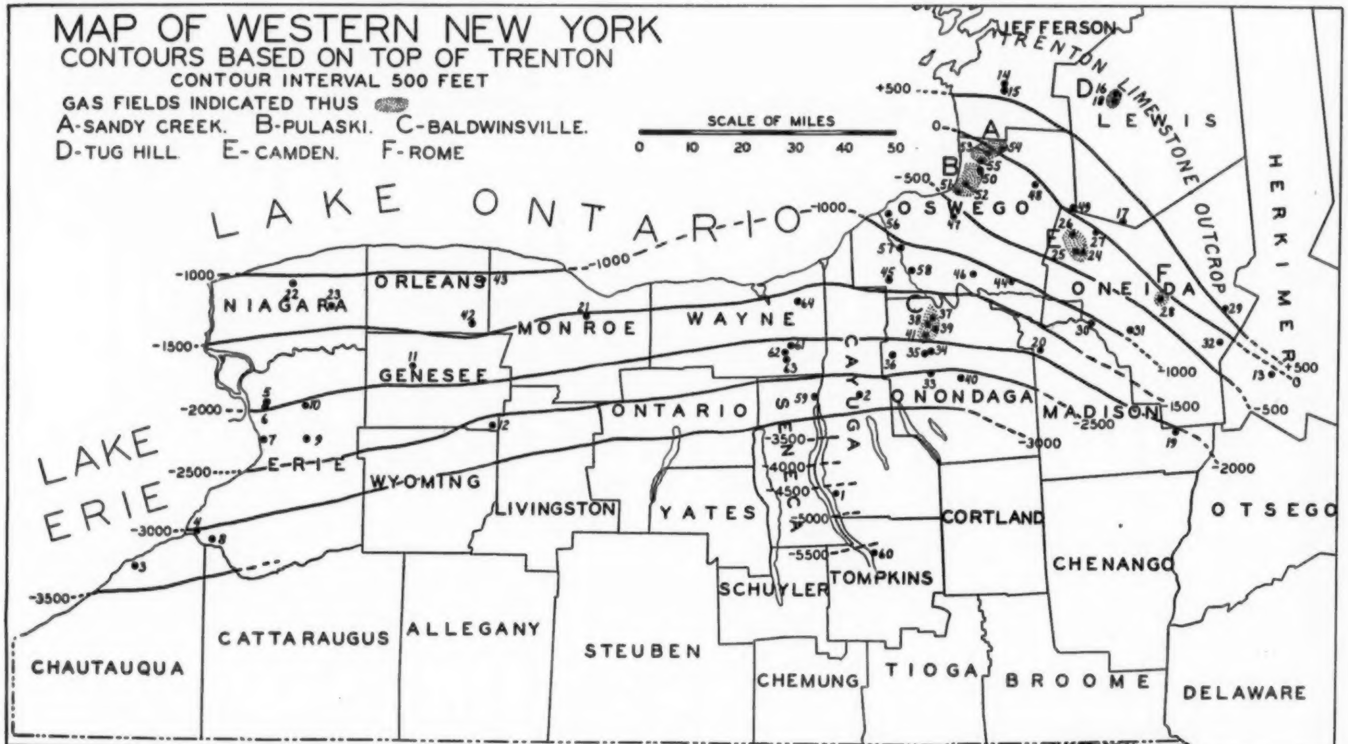

MAP OF WESTERN NEW YORK
CONTOURS BASED ON TOP OF TRENTON
CONTOUR INTERVAL 500 FEET
GAS FIELDS INDICATED THUS
A-SANDY CREEK. B-PULASKI. C-BALDWINSVILLE.
D-TUG HILL. E-CAMDEN. F-ROME
SCALE OF MILES
0 10 20 30 40 50
LAKE ONTARIO
LAKE ERIE
TRENTON LIMESTONE OUTCROP
JEFFERSON
LEWIS
HERKIMER
OSWEGO
ONEIDA
NIAGARA
ORLEANS
MONROE
WAYNE
CAYUGA
ONONDAGA
MADISON
OTSEGO
GENESEE
ONTARIO
SENECA
ERIE
WYOMING
LIVINGSTON
YATES
CORTLAND
CHENANGO
SCHUYLER
TOMPKINS
CHAUTAUQUA
CATTARAUGUS
ALLEGANY
STEUBEN
CHEMUNG
TIOGA
BROOME
DELAWARE
N.Y. State Museum

FIG. 2

TABLE II

Well Data for Subsurface Map of Trenton Limestone

Map No.	County	Township	Name of Well	Elevation in Feet	Depth to Trenton in Feet	Elev. Top Trenton Referred to Sea-Level
1	Cayuga	Ledyard	Mahaney	830	5,501	−4,671
2		Throop	Old Auburn	560	3,327	−2,767
3	Chautauqua	Dunkirk	Cassety	660	4,010	−3,350
4	Erie	Brant	Bemus Pierce	740	3,750	−3,010
5		Buffalo	City Hospital No. 1	680	2,600	−1,920
6		Buffalo	City Hospital No. 2	680	2,665	−1,985
7		Buffalo	South Park	600	2,960	−2,360
8		Collins	George Button	660	3,835	−3,175
9		Elma	Spring Brook	800	3,100	−2,300
10		Lancaster	Depew	680	2,855	−2,175
11	Genesee	Batavia	Gibson	870	2,750	−1,880
12		Pavilion	Martin	1,120	3,720	−2,600
13	Herkimer	German Flats	Old Ilion	405	475	− 70
14	Jefferson	Adams	White No. 1	605	6	+ 599
15		Adams	White No. 2	623	33	+ 590
16	Lewis	Harrisburg	Nefsey No. 1	1,700	602	+1,098
17		Lewis	Aikens	1,340	1,082	+ 258
18		Martinsburg	Finn	1,752	726	+1,026
19	Madison	Brookfield	Letts	1,220	3,328	−2,108
20		Sullivan	Chittenango	444	2,450	−2,006
21	Monroe	Rochester (City)	Old Rochester	506	2,006	−1,500
22	Niagara	Newfane	Coomer	340	1,435	−1,095
23		Royalton	Gasport	519	1,800	−1,281
24	Oneida	Camden	Donlon	623	935	− 312
25		Camden	Rinkle	597	928	− 331
26		Florence	Comins	913	1,164	− 251
27		Florence	Hanifan	1,122	1,165	− 43
28		Rome	Ringdahl	485	525	− 40
29		Trenton	E. D. Morgan	900	320	+ 580
30		Verona	Ainsworth	400	1,520	−1,120
31		Verona	Dodge	520	1,400	− 880
32		Utica (City)	Standard Harvester	455	562	− 107
33	Onondaga	Camillus	E. K. Monroe	861	3,350	−2,489
34		Camillus	Portland Cement	415	2,696	−2,281
35		Camillus	Sherwood	480	2,700	−2,220
36		Elbridge	Ashby	425	2,618	−2,193
37		Lysander	Kendall	410	2,250	−1,840
38		Lysander	Monroe	420	2,250	−1,830
39		Lysander	Names	430	2,270	−1,840
40		Onondaga	Yenny	1,013	3,730	−2,717
41		Van Buren	Spaulding No. 2	425	2,404	−1,979

Map No.	County	Township	Name of Well	Elevation in Feet	Depth to Trenton in Feet	Elev. Top Trenton Referred to Sea-Level
42	Orleans	Clarendon	Emilkampf	660	1,972	−1,312
43		Murray	Holley	380	1,420	−1,040
44	Oswego	Constantia	Parker	500	1,535	−1,035
45		Granby	Leo Gray	409	1,700	−1,291
46		Hastings	Rice	420	1,609	−1,189
47		Mexico	Earl	350	1,027	− 677
48		Orwell	Phineas	900	925	− 25
49		Redfield	Ciaccio	1,165	1,040	+ 125
50		Richland	Maltby	355	515	− 160
51		Richland	H. Manwaring	281	651	− 370
52		Richland	Stewart No. 1	345	585	− 240
53		Sandy Creek	Beldock	480	520	− 40
54		Sandy Creek	Kinney	780	630	+ 150
55		Sandy Creek	Woodard No. 1	290	400	− 110
56		Scriba	Oswego City	300	1,196	− 896
57		Volney	E. Van Buren	320	1,370	−1,050
58		Volney	Vogelsand No. 1	380	1,400	−1,020
59	Seneca	Tyre	Tyre	402	3,000	−2,598
60	Tompkins	Lansing	Farkas	850	6,376	−5,526
61	Wayne	Galen	Ethel Arnold	461	2,540	−2,079
62		Galen	Harper No. 3	405	2,590	−2,185
63		Galen	Noble	410	2,630	−2,220
64		Wolcott	Wolcott	317	1,950	−1,633

which had initial flows from 2 million to 3 million cubic feet of gas a day. The gas was used for commercial purposes and the supply was rapidly depleted, although the wells continued with small volume for several years. Recently, ten wells, 600–900 feet in depth, have been drilled in the vicinity of Rome. As in the earlier operations, pressures declined rapidly until at present only moderate flows are obtained.

Since 1934 sixteen wells were drilled, near the village of Camden, half of which proved productive. The top of the Trenton is reached at depths varying from 900 to 1,100 feet, gas occurring at many horizons in that formation. Some large initial flows were obtained, the average rock pressure in the field being about 800 pounds. A pipe line has been recently constructed to supply the village of Camden with gas.

Lewis County.—Since 1933, several wells have been drilled on the Tug Hill plateau in Lewis County. Only moderate flows of gas were obtained in these operations. This gas is transported by pipe line to the village of Lowville.

Oswego County.—The Sandy Creek gas field was first opened in

1889 and has had continuous production ever since. The top of the Trenton is found at depths ranging from 385 to 600 feet and wells are completed in the Trenton at depths ranging from 1,000 to 1,200 feet. About 62 wells have been drilled. The gas is used to supply the villages of Sandy Creek and Lacona. Two miles southwest of the Sandy Creek field lies the Pulaski field, which is here described in detail.

PULASKI GAS FIELD

The Pulaski gas field is located in Oswego County, along the southeastern shore of Lake Ontario (Fig. 3). The field was named from the village of Pulaski, where the first gas wells were drilled on the eastern border of the field. Pulaski is also the type locality of the Pulaski shale. The size of the developed field is about 18 square miles, with the 73 wells fairly evenly spaced over the entire area. With a single exception the wells are in the town of Richland.

TOPOGRAPHY

The Pulaski gas field occupies a glaciated region over much of which lies a heavy mantle of glacial material, including drumlins and kames, with a thickness up to 100 feet. These have been modified by the waters of glacial Lake Iroquois, which in late glacial time covered the region. Rock outcrops are scarce, but where they occur the best exposures may be found along Salmon River, a post-glacial stream which flows westward from the village of Pulaski, through the center of the gas field, to Lake Ontario. Erosion by the Salmon River has somewhat modified the rolling nature of the plain between Pulaski and the lake. In elevation, the surface of the gas field varies from 246 feet, the level of Lake Ontario, to about 425 feet in the vicinity of Pulaski. On the west, Lake Ontario, together with several landlocked bays, limits development in that direction.

GEOLOGY

In the following section is shown the stratigraphic position of the formations present in the Pulaski field.

			Thickness in Feet
Pleistocene	Sand and gravel		0– 96
Ordovician	Lorraine, or "Hudson River"	Pulaski Frankfort	200– 250
	Utica shale		100– 250
	Trenton limestone including Black River beds		600
Cambrian	Little Falls dolomite		200
	Potsdam sandstone		35– 90
Pre-Cambrian	Granite (Well No. 12, Fig. 3) at		1,425

Ordovician formations.—The surface formation in the Pulaski field is the Pulaski shale, which crops out along Salmon River in the village of Pulaski, the type locality, and was given its name by Vanuxem in 1840. The exposures at Pulaski—about 50 feet thick—are predominantly of gray shales alternating with thin sandstone beds many of which are calcareous. Fossils characteristic of the formation are abundant and include pelecypods, brachiopods, and trilobites. From well cuttings it has been impossible to draw a dividing line between the Pulaski and the next underlying formation, the Frankfort shale (1840, Vanuxem). In sections near by, where the Pulaski is capped by the Oswego sandstone and its base is determined by its fossils, it has a thickness of about 400 feet. The Pulaski has yielded small quantities of gas in Onondaga County.

On account of the incomplete exposures of the formation at Pulaski, Emmons (1842) substituted the name Lorraine, but not recognizing the Frankfort, he extended the term to include all the beds down to the Utica shale, thus making the Lorraine the exact equivalent of the "Hudson River" group as used in this section by Vanuxem and by Hall in their final reports (1842, 1843). The term Lorraine, therefore, is properly and with historic accuracy to be regarded as the inclusive designation of which Frankfort is the lower and Pulaski the upper unit member.

In well samples the upper and lower limits of the Frankfort shale (1840, Vanuxem) can not be readily distinguished from either the Pulaski or the Utica. The beds are mainly black and gray argillaceous shales. At the type section 60 miles southeast of Pulaski, the Frankfort has a thickness of 500 feet, is overlain by the Oneida conglomerate (Silurian) and its fauna shows a close relationship to that of the Utica shale. Only small flows of gas have been found in the Frankfort shale.

The Utica shale is a widespread formation characterized by its dark color, and well records seem to indicate its presence throughout western New York. In the Pulaski field the division between the Utica and the Trenton limestone is sharply defined, whereas in other localities of the state the base of the Utica is commonly calcareous and the dividing line is not so apparent. Inconsistency in thicknesses of the Utica as recorded in logs from the Pulaski field is due to difficulty in determining the upper boundary of the formation. Although containing much carbonaceous material, the Utica shale ordinarily produces only small quantities of gas. The largest flows from the Utica have been reported from the Baldwinsville field of Onondaga County where one well produced for a number of months at the rate of more than one million cubic feet daily.

The Trenton limestone, as the term is used in the Pulaski field, includes also at its base members of the Black River group which embrace the Watertown, Leray, and Lowville ("Birdseye") limestones. The combined thickness of all of these formations is 600 feet, of which about 100 feet belong to the Black River group. Gas is found at various horizons throughout the entire thickness of 600 feet.

Cambrian formations.—The 200 feet of dolomite below the Trenton is correlated with the Little Falls dolomite and is of Cambrian age. The formation is the "Calciferous" of the older reports. At the type locality southeast of the Pulaski field, the rock is a highly magnesian, sparsely fossiliferous rock with considerable amounts of silica. It contains numerous cavities which are the source of many perfect quartz crystals widely known as Little Falls "diamonds." Associated with the crystals in the cavities, and in the bedding planes as well, may be found many specimens of anthracite having a fixed-carbon content of 93 per cent. Quartz crystals are also found holding inclusions of the anthracite. The Little Falls has not been productive of any gas.

The Potsdam sandstone is the lowest Paleozoic formation of the region with a thickness of 35–90 feet, as indicated by logs of wells in the Pulaski and adjacent areas, although passage beds (Theresa) between the Potsdam and the Little Falls make it impossible to establish the exact boundary. Only one well in the Pulaski field, number 12 on the structure map (Fig. 3), has been drilled through the Potsdam sandstone. The well was a dry hole. Gas in the Potsdam sandstone has been found in at least two wells of the district. At Parish 10 miles south of the Pulaski field, a well was drilled to the pre-Cambrian, which was reached at 2,140 feet. In this well, gas, with a registered pressure of 340 pounds, was reported in the Potsdam sandstone not more than 25 feet above the pre-Cambrian rocks. A well near Warners, Onondaga County, about 30 miles southwest of the Pulaski field, yielded a supply of gas from the Potsdam sandstone at a depth of 3,580 feet. The initial flow was in excess of 100,000 cubic feet daily, with a reported rock pressure of 800 pounds.

Pre-Cambrian.—The pre-Cambrian rocks have been reached by the drill in numerous wells east and south of Lake Ontario and as far west as Lake Erie. Well records seem to indicate that the present dip of the surface of the pre-Cambrian corresponds with that of the early Paleozoic sediments, thus implying that the pre-Cambrian surface was a peneplain on which the sediments were deposited. Wells drilled into the pre-Cambrian encounter not only granite and closely related rocks, but also the metamorphosed sedimentary limestones of the

earliest pre-Cambrian (Grenville series). One well recently drilled in Oneida County reached the top of the pre-Cambrian at a depth of 2,420 feet. Penetrating limestone, but not knowing the age of the formation, the driller continued 375 feet in the pre-Cambrian and reported slight flows of gas from these pre-Cambrian (Grenville) limestones. Whatever may have been the actual facts in regard to this occurrence, the presence of natural gas has been definitely recorded in the Grenville rocks of the zinc mine at Edwards, St. Lawrence County, New York, and has been described by John S. Brown.[4] The St. Lawrence County locality is about 60 miles northeast of the Pulaski field. During recent months Brown has reported further occurrences of natural gas in the Edwards mine.

HISTORY AND DEVELOPMENT OF THE PULASKI FIELD

The Pulaski field lies 35 miles southwest of the pre-Cambrian rocks of the Adirondacks, along the border of which the Trenton limestone is typically exposed. Gas seepage from the limestone, and from some of the higher formations as well, had been noted in various localities, but previous to 1888 only a few shallow tests had been made. These were principally in Jefferson County, where the Trenton is either surface rock or is found only a short distance below the surface.

The discovery, in the Trenton of Ohio, of large supplies of gas at Findley in 1884, and of oil at Lima during the following year, was the incentive for the beginning of an intensive drilling campaign to find these products in the Trenton of New York. Naturally, the first attempts were in those counties southwest of the Adirondacks where the depth to the Trenton was not great and surface indications of gas seepage gave some encouragement to prospectors that natural gas or oil might be found in the rocks beneath. Oil, or course, was the chief objective, but the Trenton of New York yielded no oil at that time or at any time since.

Two of the gas fields, discovered during this early period and still producing, are the Sandy Creek field, opened in 1888, and the Pulaski field near by, where drilling began in 1891. In the Pulaski field, the first two wells were drilled in the village of that name, demonstrating the presence of gas in the Trenton. Since that time 73 additional wells, of which ten were dry holes, have been drilled from time to time, three as recently as the year 1934. With the exception of the two original wells, the locations of these wells are shown on the accompanying structure map with contours based on the top of the Trenton. The

[4] John S. Brown, "Natural Gas, Salt and Gypsum in the Pre-Cambrian Rocks at Edwards, New York," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 16 (1932), pp. 727-35.

numbers assigned to the wells indicate approximately the order of drilling.

Field characteristics.—The rocks in the Pulaski area have a general southwest dip of 43 feet to the mile away from the pre-Cambrian Adirondack mass. This does not differ materially from the regional dip of the Paleozoic rocks over much of western New York, although in some sections the southern component of the dip is larger. As indicated on the map (Fig. 3) there is a slight structural nose or terrace in the Pulaski field, trending northeast and southwest. This structure has had little or no influence on gas accumulation.

Although generally referred to as a limestone formation, the Trenton really consists of a series of alternating limestones and shales. Moreover, the limestone beds are not of sufficient porosity to serve as reservoir rocks, nor are they dolomitic, as are the Trenton beds of Ohio, which have been so productive of oil and gas. In the various Trenton fields of New York, gas is found in shale partings and shale beds and in cavities, seams, and joints within the limestone itself. Coral reefs within the Trenton are also believed to serve as a source of some of the gas.

There are no definite horizons at which gas occurs in the Trenton formation in any of the developed fields. In a single well, gas may be found in as many as 20 horizons distributed through the entire thickness of the formation. In drilling operations it may be observed that as the drill passes from a limestone layer into a break or shale bed, gas issues from the well. If the well is drilled deeper, other flows are found as the various beds of limestone are penetrated, and thus the total flow of a well is derived from a number of independent gas horizons.

Rock pressures.—Rock pressures in the Pulaski, as well as in the other Trenton fields, vary considerably. In the Pulaski field, rock pressure ranges from 160 pounds to more than 1,000 pounds. In the Baldwinsville field, a well 2,610 feet deep had a rock pressure of 1,350 pounds; in the old Fulton field in Oswego County, a well 1,700 feet deep had a pressure of 1,525 pounds. At Clyde, Wayne County, a well drilled into the Trenton developed a rock pressure of 1,900 pounds at a depth of 2,733 feet. The high pressures developed in some of the wells are due to pockets, which rapidly decline in pressure as gas is withdrawn. When the pockets are struck, drilling tools and casing are often violently hurled from the well. Under such circumstances after the flow has subsided, the well may be repaired and deepened or it may continue to produce with a small volume for several years.

Neighboring wells are, as a rule, independent of one another, so far as the source of gas is concerned, and commonly vary greatly in

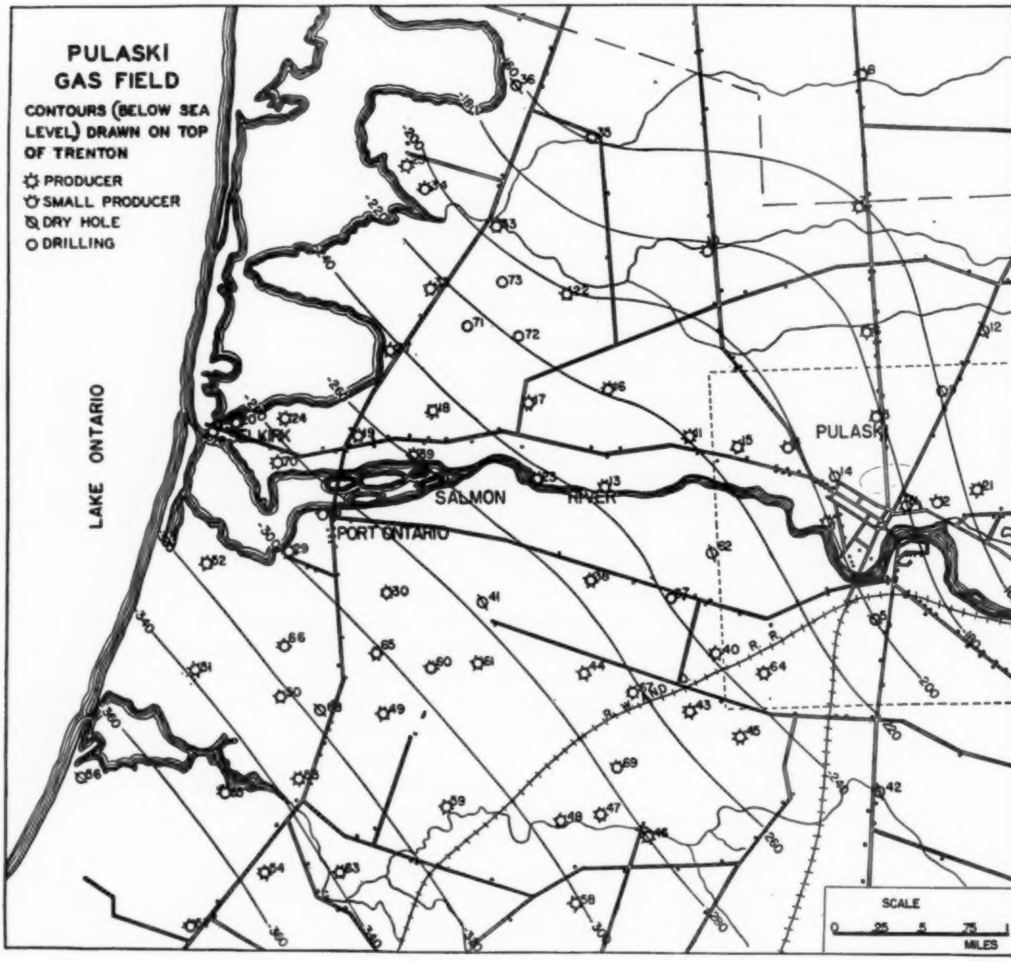

PULASKI
GAS FIELD
CONTOURS (BELOW SEA LEVEL) DRAWN ON TOP OF TRENTON
PRODUCER
SMALL PRODUCER
DRY HOLE
DRILLING
LAKE ONTARIO
ELKIRK
SALMON RIVER
PORT ONTARIO
PULASKI
SCALE
0 .25 .5 .75 1
MILES

Fig. 3

rock pressure. As an illustration, well number 40 on the Pulaski map (Fig. 3) was drilled in 1907 to a depth of 1,205 feet and had a rock pressure of 425 pounds. In 1929, well number 67, nearly ½ mile distant, was drilled to the same depth and had a pressure of 600 pounds. In some instances in the Pulaski field a direct underground connection between two wells has been evident, thus making it possible to withdraw the gas from both through a single outlet.

Drilling practice.—In the early development of the Trenton fields, it was customary to drill the wells to the base of the Trenton before stopping. This practice resulted in a great loss of gas from the various horizons as well as from the pockets. At present, after drilling a short distance into the Trenton, the casing is set and a gathering line is laid to the well. Drilling is then resumed through the casing until an important flow of gas or pocket is found, when the drilling tools are removed and the well is connected with the distribution system. In some cases, if large pockets of gas are found, the surplus is introduced into one or more of the older wells from which the gas can be recovered later. The practice of delayed drilling as employed in the Pulaski field is an important factor in extending the life of the field. The results of recent drilling indicate that a number of good producers can be obtained by drilling between the older wells.

CONCLUSIONS

From experience gained by drilling operations during the past 40 years, it is evident that there is little hope of developing a large gas field in the relatively shallow territory near the eastern end of Lake Ontario. The best that can be expected is the development of small community fields from which the entire output of gas can be consumed locally. In other sections of New York, where the Trenton is found under a deep cover of rock, some tests have been made, but the results have been disappointing. It must be admitted, to be sure, that much of western New York remains untested, but on the basis of results obtained in the fields already developed, the prospects for finding an important gas field in the deep Trenton of western New York are not very encouraging.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 22, NO. 1 (JANUARY, 1938), PP. 100-108, 3 FIGS.

GEOLOGICAL NOTES

ELEVENTH ANNUAL FIELD CONFERENCE, KANSAS GEOLOGICAL SOCIETY, SEPTEMBER 2-6, 1937

A group of 142 geologists gathered at Pittsburg, Kansas, on the evening of September 2, 1937, to participate in the Eleventh Annual Field Conference conducted by the Kansas Geological Society. Although this trip was not so extensive as some of the former trips, the geology of the area covered is pertinent to all Mid-Continent geologists, and a keen interest was shown by those in attendance.

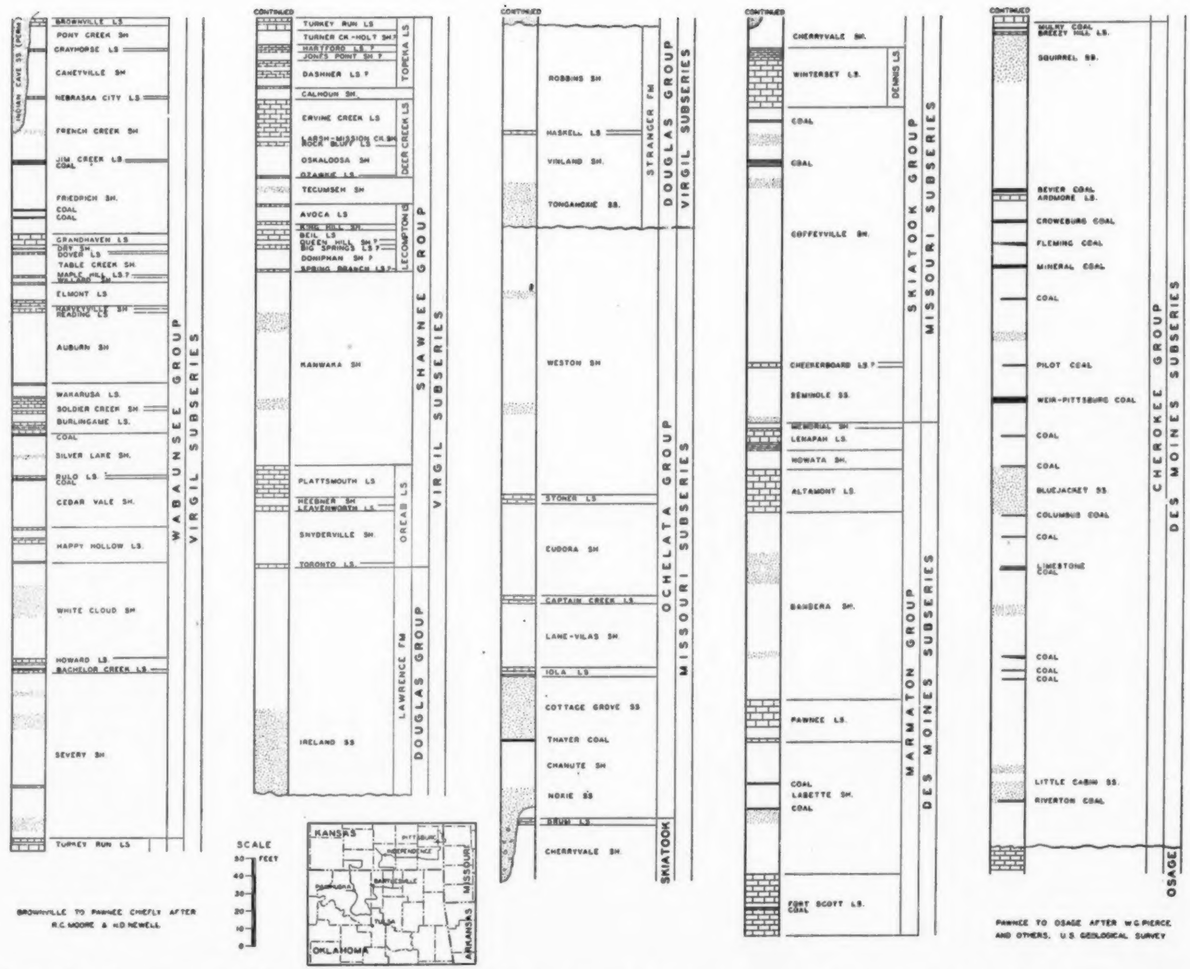
The participants represented 31 oil companies as well as many consulting geologists, 8 colleges, 5 state geological surveys, and the United States Geological Survey. The geologists came from 10 states and the District of Columbia. The caravan consisted of 46 automobiles.

Under the leadership of Raymond C. Moore, State geologist of Kansas, and Robert H. Dott, State geologist of Oklahoma, assisted by K. K. Landes, assistant State geologist of Kansas, the group spent 4 days studying the Pennsylvanian rocks exposed in southeastern Kansas and northeastern Oklahoma.

W. G. Pierce of the United States Geological Survey carried the main burden of leadership in study of the Cherokee shale the first day. The Mississippian limestone (Osage) was seen in one exposure in a recent sink hole southeast of Pittsburg. From this point, a nearly complete sequence of Pennsylvanian rocks upward to the Dover limestone in the upper part of the Wabaunsee group was studied in the course of the conference. A generalized columnar section of the rocks examined is shown in the accompanying figure.

The first day was spent studying rocks of the Cherokee and Des Moines groups, with especial emphasis on the numerous coals of the Cherokee, some of which are mined in this area. Several stone quarries and coal strip pits were visited where the more important of these coals and associated beds were examined. The possibility of making important geologic contributions by means of wide-range correlations based on detailed studies was brought out. Thus the Ardmore limestone, in the upper part of the Cherokee shale, which is equivalent to the Verdigris limestone of Oklahoma and the Rich Hill limestone of Missouri, is now known to be present from Kansas to Kentucky, and probably extends farther, both northwest and east.

The second day of the conference was spent between Independence,



Composite columnar section of Pennsylvanian rocks studied by participants of Eleventh Annual Field Conference of Kansas Geological Society.

Kansas, and Bartlesville, Oklahoma, in study of rocks of the Missouri subseries. State geologists Dott and Moore pointed out that co-operative studies between the geological surveys of Oklahoma and Kansas, aided by oil-company geologists, have made possible definite correlations of the Pennsylvanian rocks in the two states.

On the third day, the group had opportunity for further study of the Oklahoma equivalents of rocks of the Missouri group previously seen in Kansas. The stratigraphic range was extended by a study of the rocks of the upper Missouri and Virgil groups in the Osage Reservation.

The fourth and final day was spent in a survey of rocks of the Virgil group in the northern Osage area and across the state line in southern Kansas. The conference disbanded about 20 miles west of Sedan, Kansas.

The large party was handled with a minimum of confusion and the 46-car caravan departed in the mornings and returned in the evenings on a prearranged schedule which was remarkably well followed. Hotel arrangements were made and baggage correctly distributed before the group arrived each evening. These irksome duties were taken care of by the committee on arrangements consisting of John Garlough, A. E. Cheyney, R. A. Whortan, and A. L. Morrow. Harvel E. White acted as business manager.

Evening meetings were held at which talks pertinent to the geology of the area traversed were given. Stops at outcrops were less frequent than on former conferences, but were of longer duration in order to allow ample time for discussion, study, and sample collecting.

Each participant was supplied with a guide book containing detailed descriptions and measured sections of the beds seen at each outcrop examined, as well as a running log of all of the country traversed between stops. The book contains a combined Oklahoma-Kansas geologic map of the area covered, with the route and all stops shown by appropriate symbols. It is profusely illustrated with detailed sections, correlation charts, and composite sections. In addition to these data the book contains the following articles.

Raymond C. Moore, "Upper Carboniferous Rocks of Southeastern Kansas and Northeastern Oklahoma"
W. G. Pierce and W. H. Courtier, "Rocks and Structure of Southeastern Kansas"
G. E. Abernathy, "The Cherokee Group of Southeastern Kansas"
John M. Jewett, "Lateral Changes in the Lower Missouri Beds of Southeastern Kansas"
Raymond C. Moore and Norman D. Newell, "The Missouri-Virgil Boundary in Southern Kansas and Northern Oklahoma"
Raymond C. Moore, Norman D. Newell, Robert H. Dott and Joseph L. Borden, "Definition and Classification of the Missouri Subseries of the Pennsylvanian Series in Northeastern Oklahoma"

T. E. WEIRICH, "Petroleum Geology of Nowata and Washington Counties, Oklahoma"
KENNETH K. LANDES, "The Southeastern Kansas Coal Field"
KENNETH K. LANDES, "The Tri-State Zinc-Lead District"
RAYMOND C. MOORE, "Annotated Index of Stratigraphic Terms Used in Pennsylvanian and Lower Permian Sections of Southeastern Kansas and Northeastern Oklahoma"
JOHN M. JEWETT, "Selected Bibliography"

Copies of the guide book may be secured from the Kansas Geological Society for $4.50 each.

JOSEPH L. BORDEN

TULSA, OKLAHOMA
November 23, 1937

NEW INTERPRETATION OF MONONGAHELA-DUNKARD CONTACT, WASHINGTON COUNTY, OHIO

Due to a recently renewed interest on the part of the petroleum industry in the Cambridge arch and associated structures of southeastern Ohio and northern West Virginia, the following information concerning the stratigraphy and surface expression of this structure should be of use. It is well known, however, that in this region the structure as determined by surface stratigraphy can not be considered a true picture of the structure at depth.

In eastern West Virginia and southwestern Pennsylvania the Monangahela-Dunkard contact has been drawn at the top of the Waynesburg coal.[1] Partly due to lack of adequate fossils this horizon has been correlated over wide areas by purely physical means. In Washington County, Ohio, the Waynesburg coal does not occur as a persistent thick bed, but is thin and lenticular. Various thin lenses and pockets of coal and carbonaceous shale occur here, which can not be definitely assigned to any named coal horizon; also the Little Waynesburg, which occurs within 15 feet of the Waynesburg, is lenticular. Undoubtedly in certain exposures, where no coal occurs at the stratigraphic position of the Waynesburg of the type locality, the contact has been drawn at the top of one of these lenses. White[2] correctly correlates the important coal occurring a few feet above creek level on Meigs Creek, Morgan County, Ohio, with the Sewickley. The Sewickley-Meigs Creek coal, which occurs near the middle of the Monongahela, is more persistent in Ohio than the Waynesburg, and in the area considered can be traced with much more certainty.

The Macksburg coal, which is well exposed high in the hill at

[1] I. C. White, "Stratigraphy of the Bituminous Coal Fields of Pennsylvania, West Virginia, and Ohio," *U. S. Geol. Survey Bull. 65* (1891), p. 20.

[2] *Ibid.*, p. 52.

Macksburg, northeastern Washington County, was correlated with the Waynesburg by White,[3] from a section measured and described by Minshell.

By measuring numerous detailed sections in the intervening territory and determining elevations at every accessible mine entry and outcrop,[4] it is established that the coal above Macksburg is the equivalent of the coal in the bed of Meigs Creek. On the assumption of the validity of the Sewickley-Meigs Creek correlation by White, the Monongahela-Dunkard contact in the Macksburg area, northeastern Washington County, lies more than 100 feet above the position assigned to it by these workers. From the central area of the structure the Dunkard has been extensively removed by erosion. Also the Cambridge arch, instead of involving only slight reversals of the east-southeast regional dip, represents a structure with west-southwest dips exceeding 75 feet per mile.

JOHN C. FRYE

IOWA CITY, IOWA
December 11, 1937

ACTIVE FAULTING IN LAVACA COUNTY, TEXAS

Evidence of active faulting in the Willis formation of Lavaca County, Texas, was recently pointed out to the writers by Raymond Goodrich of Houston. The evidence is in the form of a large crack in rather sandy soil. The fault appears to have a more or less continuous movement at present.

The fault is located in the eastern part of the county in the Patrick Bradley Survey on the E. Pohl tract. The strike of the fault is approximately N. 60° E. The fault may be traced on the surface for a distance of approximately 2,000 feet. The opening in the surface is 4–6 inches wide and is known to have been in existence for the past 20 years. The surface is flat and covered with a dense growth of post oaks, but almost void of grass or weeds. The soil is very loose and sandy, though a few places with a considerable amount of clay in the sand are fairly well consolidated. The fault is more prominent in the consolidated formation, but does not completely lose its identity in the loose sand. The age of this surface formation is Pliocene-Pleistocene.

The most convincing evidence of present movement of the fault

[3] *Ibid.*, p. 52.

[4] J. C. Frye, "Geology of a Portion of the Lower Muskingum Valley, Ohio," unpublished thesis, State University of Iowa (1937), appendix *A* and structure map.

FIG. 1.—Fault splitting tree, Lavaca County, Texas.

is found in the deformed post oak trees along the crack. In one instance a post oak about 8 inches in diameter has been alternately split by the movement at the base and the split healed by normal growth of the tree. The scar left by this action is about 1 inch wide and the recent unhealed split is about $\frac{1}{8}$ inch wide. The split continues from the roots upward to about 1 foot above the ground. In another instance, a root about 2 inches in diameter has been pulled from a post-oak tree 12 inches in diameter. There is still other evidence that trees and stumps have probably been split and deformed by the movement, but this other evidence is not as convincing as the cases cited.

There is no evidence of the dip of the fault plane or the amount of vertical or horizontal displacement, but in one place, where there

is little grass growing on the surface, an apparent scarp of about 3 inches was noted.

It is believed that this is one of the few cases in the Gulf Coast region where an active fault is noted.

DOUGLAS E. BELL
V. A. BRILL

HUMBLE OIL AND REFINING COMPANY
HOUSTON, TEXAS
December 2, 1937

REVISION OF STRATIGRAPHY OF DRY CREEK AND GOLDEN STRUCTURES, CARBON COUNTY, MONTANA

In 1936 the writer published a report on the series of structures between Nye and Bowler, Montana.[1] At the time of publication the possibility of incorrect identification of formations in the vicinity of Dry Creek and Golden structures was recognized. For this reason the stratigraphy of these structures was presented tentatively as stated in a footnote to that effect.[2] Since publication additional work has been done on the stratigraphy of the Dry Creek and Golden structures, with the result that a revision of stratigraphic names is necessary. The units under question have been traced by Stow[3] continuously from Dry Creek and Golden to Polecat Bench, north of Powell, Park County, Wyoming, and have been correlated with the faunal zones as identified by Jepsen.[4]

As a result of this correlation, the writer herewith submits a revised geologic map of Dry Creek and Golden structures (Fig. 1). Several changes have been made in the mapping and more details of structure added to part of the map published in 1936. The stratigraphic section exposed in the area included in Figure 1 is summarized, as follows.

	Thickness in Feet
Tertiary system	
Paleocene series	
Fort Union formation	
Upper unit in which sandstones are common (corresponds in part with Tongue River member). Succession of irregularly bedded, commonly lenticular, medium-grained, yellow and white sandstones with streaks and seams of coal; gray sandy	

[1] C. W. Wilson, Jr., "Geology of Nye-Bowler Lineament, Stillwater and Carbon Counties, Montana," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 20, No. 9 (September, 1936), pp. 1161–88.

[2] *Op. cit.*, p. 1163.

[3] M. H. Stow, personal communication.

[4] G. L. Jepsen, "Stratigraphy and Paleontology of the Paleocene of Northeastern Park County, Wyoming," *Proc. Amer. Philos. Soc.*, Vol. 69 (1930), pp. 463–528.

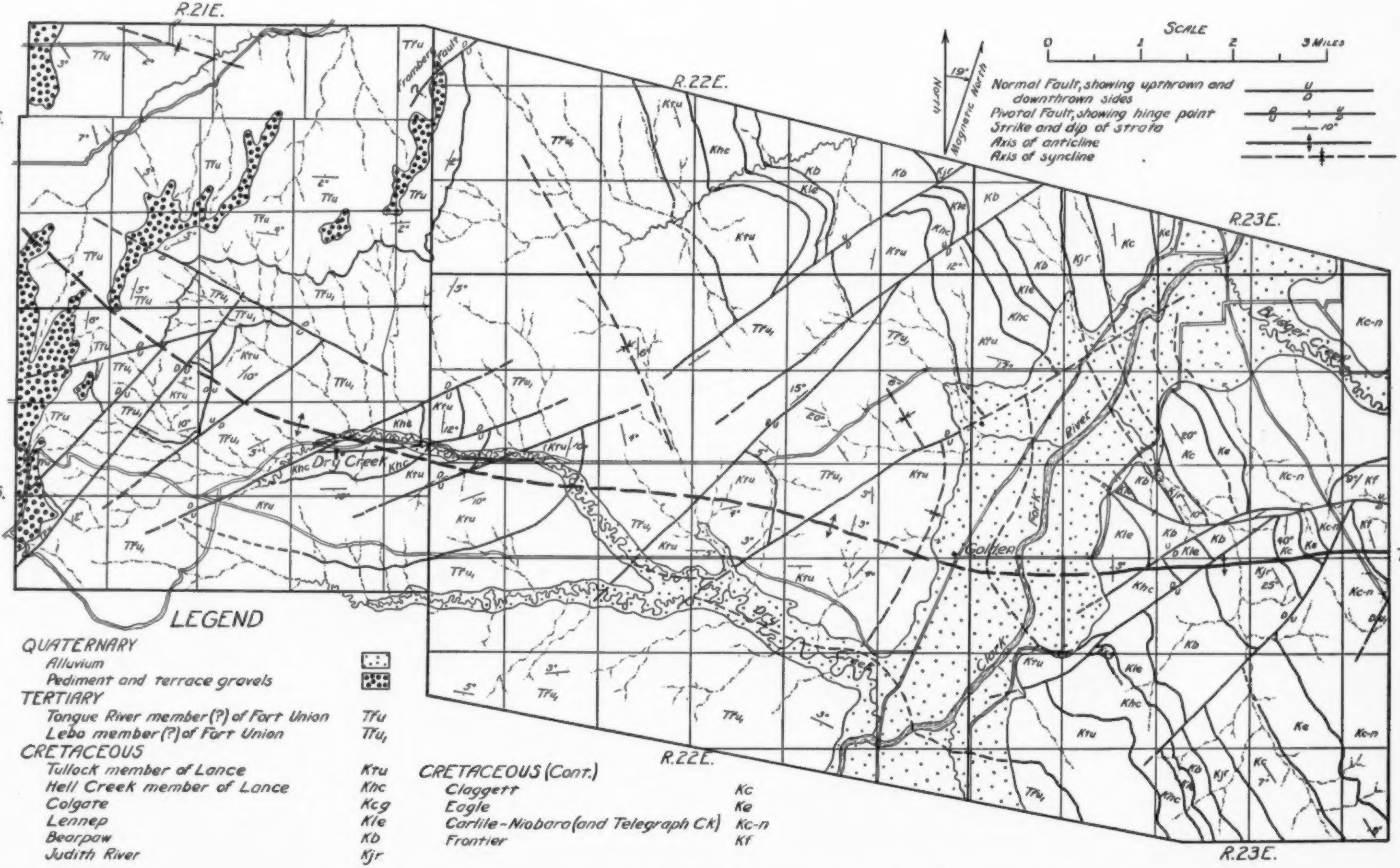


FIG. 1.—Areal geologic map of Dry Creek and Golden structures, Carbon County, Montana.

shale and mudstone; brown carbonaceous shale; thin layers of buff limestone; and local lenses of conglomerate. Total thickness not recorded, but is several thousand feet		
Lower badland-forming unit (corresponds in part with Lebo member). Greenish gray, yellow, and olive-drab shale and mudstone interbedded with irregularly bedded sandstone lenses. Locally conglomeratic		
South of lineament		3,500*
North of lineament...indeterminate due to faulting, but at least 1,000 feet		
Cretaceous system		
Lance formation (Tertiary (?) according to U. S. Geol. Survey)		
Tullock member		
Alternation of massively bedded, buff-to-white, moderately persistent sandstones and gray mudstone		450
Hell Creek member		
Greenish gray, yellow, and olive-drab shale and mudstone; bentonitic clays; and lenses ranging from rusty yellow to dark brown sandstone		240
Colgate sandstone		
White-to-light gray, irregularly bedded sandstone		20
Lennep sandstone		
Alternation of slabby, brown, andesitic sandstones that weather into dark brown and dark gray mudstone. Numerous brownish red concretions		250
Bearpaw shale		
Dark gray mudstone with layers of andesitic sandstones that weather into dark brown lenticular masses		275
Judith River formation		
Alternation of gray and brown, andesitic sandstones, brown carbonaceous shale with coal streaks, and brown sandy shale		575
Claggett shale		
Gray and buff, massive sandstone that weathers into smooth, rounded forms (Parkman sandstone member)	300	
Gray sandy shale; thinly bedded sandstone; and a few massive sandstones	350	
Total		650
Eagle sandstone		
Alternation of buff sandstone; brown carbonaceous shale with streaks and seams of coal; and gray shale	200	
Massive, light buff-to-gray sandstone (Virgelle sandstone member)	75	
Total		275
Telegraph Creek formation		
Thinly bedded gray sandstone with some gray shale	160	
Massive sandstone	20	
Total		180
Niobrara and Carlile shales		
Black shale, containing black sideritic concretions		1,200
Frontier formation		
Massive, buff-to-light gray sandstone (Torchlight sandstone member)	85	
Alternation of gray and buff sandy shale; black shale; bentonitic clays; and buff sandstone	350	
Total		435

CHARLES W. WILSON, JR.

DEPARTMENT OF GEOLOGY
VANDERBILT UNIVERSITY
NASHVILLE, TENNESSEE
December 7, 1937

* This thickness was furnished by M. H. Stow.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 22, NO. 1 (JANUARY, 1938), PP. 109-110.

DISCUSSION

DISCOVERY RATES IN OIL FINDING

In a paper entitled "Discovery Rates in Oil Finding" published in the June, 1937, issue of the *Bulletin*,[1] Wallace E. Pratt calls attention to the declining rate of discovery of oil reserves since 1930, and he suggests that one of the major contributing factors has been the "inadequacy of our finding technique to cope with the increasing difficulty of oil finding." Since geologists are charged with the problem of maintaining the effectiveness of efforts expended in the search for oil, there can be no doubt that Mr. Pratt is focusing attention on a problem of vital importance to geologists. But Mr. Pratt's article has led the writer to a quantitative examination of the factors that may have influenced the decline in discovery rate. This leads to the conclusion that the more important factor has been the reduction in the amount of effort expended in the search for oil, and that the less important factor has been a decline in the effectiveness of this effort. The facts supporting this view are presented in a paper by Joseph E. Pogue on "The Economic Structure of the American Petroleum Industry" which was published in the February, 1937, issue of the *Bulletin*.[2] It seems clear to the writer that relatively large reserves and low prices have been chiefly responsible for the decline in discovery rate since 1930; and that under the stimulus of rising prices, there will be a greater amount of effort spent in the search for oil which should in turn result in a more rapid rate of discovery unless geologists fail in their job.

Mr. Pogue proposes the number of dry holes drilled as an acceptable measure of the volume of effort going into exploration, and he shows that there is a direct correlation between price of crude oil, number of dry holes drilled, number of oil wells completed, and volume of oil discovered.

In Figure 4, page 157, the correlation between price and number of dry holes is manifest. In Figure 5, page 158, the number of dry holes and the number of oil wells completed in any one year are plotted against the weighted average price of crude oil for that year. Thus there is a cross and a dot with the same ordinate for each year. It is clear that taking the industry as a whole the number of dry holes drilled and the number of oil wells completed are directly proportional to the price, and that the more dry holes drilled, the more wells there are completed as producers. Table II on page 159 shows the trend of crude oil discoveries compared with price and number of dry holes drilled. Thus in the five-year period, 1926–30, during which the average price of crude was $1.35 per barrel, there were 36,983 dry holes drilled, and 9,950 million barrels added to our reserve; and in the five-year period, 1930–35, during which the price was $.83 per barrel, only 19,763 dry holes were drilled, and 4,120 million barrels of crude were discovered.

Mr. Pogue also gives an index of the effectiveness of effort, which is the factor to which Mr. Pratt calls attention. This index is the barrels of oil discovered per dry hole, and figures for it are given in the last column of Mr. Pogue's Table II, page 159. They show that the oil discovered per dry hole

[1] *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 21, No. 6 (June, 1937), pp. 697–705.

[2] *Ibid.*, Vol. 21, No. 2 (February, 1937), pp. 149–98.

did decline from 270,000 barrels for the period 1926–30, to 208,000 barrels per dry hole for the period 1931–35. But if this decline were the major factor in the lower rate of discovery, there should have been a more nearly equal amount of prospecting effort in each of these periods. Actually, the effectiveness of the prospecting effort declined 23 per cent as measured by the oil discovered per dry hole, whereas the volume of effort as measured by the dry hole index declined 46.5 per cent. Therefore, although less effective effort was a contributing factor, the major factor was a smaller volume of effort.

It follows from the above that until and unless there is a more drastic decline in the adequacy of oil-finding technique to cope with the problem of finding oil, the more effort there is expended, the more oil there will be found, and that, in the industry as a whole, volume of effort is related to price.

By applying this economic analysis to the current situation, it is seen that the price of oil was depressed during 1931–35 by the pressure of reserves found in the preceding period. A large part of these reserves were in East Texas and were immediately available for the market. The number of dry holes drilled during 1931–35 dropped in response to the lower price, and so the rate of discovery declined. It may be predicted for the period 1935–40, that under the stimulus of a rising price, more dry holes will be drilled, more oil wells will be found, and the discovery rate will again go up. But in order to make this prediction come true, the geologist will have to succeed in discovering as much oil per dry hole drilled as he has in the past. This is the increasingly difficult task which confronts geologsts and to which Mr. Pratt is calling attention.

F. F. CAMPBELL

HOUSTON, TEXAS
October 20, 1937

CORRECTION

QUARTERMASTER UNCONFORMITY OF WEATHERFORD AREA, OKLAHOMA

In the discussion, "Quartermaster Unconformity of Weatherford Area, Oklahoma," by Noel Evans, in the December, 1937, *Bulletin*, the following corrections should be made.

Page 1531, line 19: "in the Quartermaster" should be omitted.
Line 30: "dolomite" should read *gypsum*.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 22, NO. 1 (JANUARY, 1938), PP. 111-115.

REVIEWS AND NEW PUBLICATIONS

* Subjects indicated by asterisk are in the Association library and available to members and associates.

Transactions American Geophysical Union 1937. Part I, "Reports and Papers of the General Assembly and of the Sections of Geodesy, Seismology, Meteorology, Terrestrial Magnetism and Electricity, Oceanography, and Volcanology." 263 pp. Part II, "Reports and Papers of the Section of Hydrology and of the South Continental Divide Snow Survey Conference." 400 pp. National Research Council, Washington. D. C. (July, 1937). Price, $4.00.

The *Transactions of the American Geophysical Union* deserve to be better known by geologists, for many of the brief papers in the transactions are as much geological as they are geophysical and in condensed form give pertinent information and thought on many broad geological problems.

The following papers in the 1937 volume of the *Transactions* will be of interest to geologists. Symposium on Theoretical and Observational Considerations of Importance to Further Studies of the Depths of the Earth: (1) C. E. Van Orstrand, "Estimation of Temperatures at Moderate Depths in the Crust of the Earth"; (2) W. D. Lambert, "The External Gravity Field and the Interior of the Earth"; (3) J. B. Macelwane, "Deep Focus Earthquakes and Their Implications" (earthquakes now are known to have foci as deep as 700 km.); (4) "The Earth's Interior as Inferred from Terrestrial Magnetism"; (5) P. W. Bridgeman, "The Behavior of Matter under Extreme Conditions" (under static and shearing pressures ranging up to 50,000 kg. per sq. cm.). Other papers of geological interest are: Maurice Ewing and H. H. Hess on the gravity measurements supplemented by sonic soundings across the oceanic trough and gravity minimum of the Lesser Antilles, tracing the Bronson trough in front of Puerto Rico southward to the Venezuelan coast; G. P. Wollard, "Gravity Anomalies and Geologic Structure"; D. C. Barton, "Accuracy of Modern Gravimeter-Measurements"; J. P. Delaney, "A Note on Land Tilting" (at Buffalo, New York); W. H. Bradley, J. A. Cushman, and others in a most interesting preliminary report on the thirteen cores, most of them 2-3 meters long, which Piggot took on a profile extending from the Newfoundland Banks to the Irish Coast (some of the cores penetrated four glacial periods; good correlation could be carried across much of the profile); several reports on the sonic mapping of the North American and Central American coasts; fifteen papers on volcanic and igneous rocks; F. E. Matthes' report on the retreat and advance of glaciers at the present time; A. N. Sayre, "A Selected List of Papers Relative to Ground-Water Hydrology" (76 items); L. G. Strauf, "Report of Committee on Dynamics of Streams, 1937" (with list of 285 references); several papers on run-off and on infiltration and on infiltration rates of meteoric waters into the soil and subsurface; nine papers on the application of geophysical methods to groundwater determinations; S. Shulits and W. E. Corfitzen, "Bed Load Transportation and the Stable Channel Problem" (covers transportation and deposition of silt in streams; 21 references). Petroleum engineers may be interested in: (1) R. M. Leggette's paper, "The Mutual Interference of Artesian Wells

on Long Island, New York" (changes of rate of pumping at one well are felt over an area of 150 square miles); (2) W. E. Code, "Some Observations on Well Characteristics" (artesian wells); and (3) C. S. Adams and A. C. Swinnerton, "Solubility of Limestone" (17 references). Texans may be interested in R. Lowry's "Floods in Texas," which lists the 75 places in Texas which have had recorded rainfalls of 10 inches or more in 24 hours; and of the five places which had recorded rainfalls of more than 20 inches in 24 hours.

Many members of the Association might be interested in joining the A. G. U. The dues are nominal, and any scientist of standing who is interested in the application of physics and physical principles to the earth or its atmosphere is eligible to membership.

DONALD C. BARTON

HOUSTON, TEXAS
November, 1937

"List of Arkansas Oil and Gas Wells," *Arkansas Geol. Survey Inform. Cir. 10* (1937). Compiled under the direction of George C. Branner, assisted by W. P. A. Project No. 165-63-6999 (Little Rock). 103 pp. Price, $1.50.

This publication contains the history of all the known wells drilled in the state of Arkansas before October 31, 1936. It includes data on the development, number of wells drilled, quantity and value of extracted products with graphs showing daily average production, maps showing the location of producing fields, wildcat wells and other valuable information concerning oil and its possibilities in Arkansas. The arrangement of data falls under three headings; first, the statistics of the oil industry in Arkansas; second, the list of wells drilled by counties wherein they are arranged in alphabetical order of the companies drilling them with locations, elevations, dates, and total depths, also where the log, if any, is on file; and third, the locations of wildcat wells on well drawn county maps numbered in order for reference to identify them in legends with each map.

As the wells listed in this circular number 2,109, it is remarkable how few errors have been found since publication. These errors are easily discovered and will not cause confusion to those using the material.

The arrangement of the data and its presentation is most satisfactory and valuable to prospectors interested in Arkansas, especially those who contemplate operations there or who have operated but a short time. Its compact form makes it convenient for all those interested in that state and they will find it a most valuable compilation to have in their office.

E. R. BROCKWAY

SHREVEPORT, LOUISIANA
December 15, 1937

RECENT PUBLICATIONS

ENGLAND

*"The English Bartonian Nummulites," by Dennis Curry. *Proc. Geol. Assoc.*, Vol. 48, Pt. 3 (London, October 28, 1937), pp. 229-47; 2 pls. of fossils.

GENERAL

*"A Quarter Century of Progress in Petroleum Engineering Concepts," by Stanley C. Herold. *Mining and Metallurgy* (New York, December, 1937), pp. 554–56; 3 figs.

*"Hardening of Mud Sheaths in Contact with Oil, and a Suggested Method for Minimizing Their Sealing Effect in Oil Wells," by C. P. Bowie. *U. S. Bur. Mines R. I. 3354* (Washington, D. C., November, 1937). 25 mim. pp.

**Ground Water*, by C. F. Tolman. "Covers the occurrence of water under ground and the principles governing its movements, with emphasis on geologic control." 593 pp., 189 figs. 6×9 inches. Cloth. McGraw-Hill Book Company, New York (1937). Price, $6.00.

The Flow of Homogeneous Fluids through Porous Media, by M. Muskat. 763 pp., 278 figs. 6×9 inches. Cloth. McGraw-Hill Book Company, Inc., New York (1937). Price, $8.00.

**Early Man*. Edited by George Grant MacCurdy. 362 pp. 27 pls., 54 text cuts. Cloth. J. B. Lippincott Company, New York (1937). Price, $5.00.

*"One Way of Finding Oil More Cheaply," by Parker D. Trask. *Oil and Gas Jour.* (November 12, 1937), pp. 120–28; 12 figs.

"A Method of Determining Porosity: a List of Porosities of Oil Sands," by D. B. Taliaferro, Jr., T. W. Johnson, and E. J. Dewees. *U. S. Bur. Mines Rept. Investig. 3352* (1937). 24 pp., 2 figs. Gives information regarding pores or voids in reservoir rocks, vitally important in scientific extraction of petroleum from natural underground reservoirs.

**Current Titles* (Engineering, Technology, Geology, Physics, Chemistry). Vol. 1, No. 1 (928 Broadway, New York, October, 1937). A new magazine of current titles and tables of contents from engineering journals. Subscription price, $3.00 a year.

**Petroleum Facts and Figures*, Fifth Edition, 1937. Approximately 250 pp. 6×9 inches. American Petroleum Institute, 50 West 50th Street, New York. Price, $0.70.

GERMANY

*"Methangasausbrüche im Altausser Salzbergbau" (Methane Seeps in Althausee Salt Mines), by Paul Lepéz. *Petrol. Zeit.* (Berlin), Vol. 33, No. 43 (November 1, 1937), pp. 8–10; 3 figs.

INDIA

*"Petrography and Genesis of the Siwalik Series," by Paul D. Krynine. *Amer. Jour. Sci.* (New Haven), Vol. 34, No. 204 (December, 1937), pp. 422–46; 4 figs.

LOUISIANA

*The Autumn number of the *Louisiana Conservation Review* (Department of Conservation, New Orleans) reports as follows on the activity of the State Geological Survey, of which H. V. Howe is director and C. K. Moresi is State geologist: "The Louisiana Geological Survey Division of the Department of Conservation has completed detailed geological and mineral resource reports on nine parishes since it was reorganized by the Legislature of 1934. Seven of these parishes are located in South Louisiana and one in North Louisiana. In addition to these parish reports, four reports dealing with the

paleontology of three of the most important oil-bearing formations of Central and South Louisiana have also been published. At the present time, reports on eight parishes in North Louisiana and four parishes in South Louisiana are being prepared. Reports on four of these parishes will be complete this winter, and should be available for distribution during the early part of 1938. For two years the Survey has been preparing a detailed report on the origin of the cap rock of salt domes with especial attention to the occurrence of sulphur. This comprehensive report should be available for distribution in 1938."

OKLAHOMA

*"Geology of the Muskogee-Porum District, Muskogee and McIntosh Counties, Oklahoma," by Charles W. Wilson, Jr., with a chapter on "Carboniferous Stratigraphy," by Norman D. Newell. *Oklahoma Geol. Survey Bull.* 57 (Norman, 1937). Prepared under coöperative arrangement with the U. S. Geological Survey. 184 pp., 5 figs., 7 pls. 6×9 inches. Paper. Price, $1.10, postpaid.

RUMANIA

*"Bohrungen im Vorlande des Oelgebietes von Rumänien" (Drilling in the Foreland of the Oil Region of Rumania), by I. Basgan. *Bohrtechniker-Zeitung* (Vienna), Vol. 55, No. 11 (November, 1937), pp. 309–13; 7 figs.

RUSSIA

*"Scientific Results of the Conference on the Permian," by D.V. Nalivkin. *Problems of Soviet Geology*, No. 7 (Moscow, July, 1937), pp. 596–603. The contents of the reports made at the conference will be published in the Abstracts and Transactions of the Seventeenth Session of the International Geological Congress. A correlation table of the Lower Permian approved by the Conference is given in English.

*"The Permian of Central Asia," by G. A. Dutkevich. *Ibid.*, pp. 603–07. Summary in English.

*"The Upper Paleozoic of the Simsky Zavod," by G. A. Dnuitriev and V. D. Nalivkin. *Ibid.*, pp. 607–17. Summary in English.

*"On the Correlation of the Permian of the Crimea and of Timor," by O. G. Tiemanskaya. *Ibid.*, pp. 617–19. Summary in English.

*"New Data on the Structure of the West Siberian Lowlands and the Turgai and Irtysh Depressions," by N. G. Kassin. *Ibid.*, pp. 630–33. Summary in English.

"Geologisch-Wirtschaftlicher Uebersich über die Oelgebiete des Kaukasus" (Notes on Economic Geology of the Oil Region of the Caucasus), by N. Polutoff. *Oel und Kohle*, Vol. 13, No. 36 (Berlin, September 22, 1937), pp. 894–901; 4 figs.

*"Paleontology and Stratigraphy of the Kuznetsk Basin." *Trans. Central Geol. and Prospecting Institute* (Leningrad and Moscow) *Fascicle 97* (1937). 172 pp., illus. Contains: "Pelecypoda from the Coal-Bearing Deposits," by D. Fedotov, 96 pp., 10 pls. of fossils (pp. 55–87, summary in English); "Brachiopods of the Indospirifer Horizon (Givetian Stage) of the Southwestern Part," by M. A. Rzonsnicky, pp. 97–138; 3 pls. of fossils (pp. 132–35, summary in English); "Ostracoda from the Kolchugino Series of the Coal-Bearing Strata," by T. N. Spizharksy, pp. 139–72; 1 pl. of fossils (pp. 165–69,

summary in English). This report is part of the service of the organization committee of the 17th International Geological Congress (1937).

WEST VIRGINIA

*"Large West Virginia Area Underlain by Oriskany," by Robert C. Lafferty. *Oil and Gas Jour.* (Tulsa, December 2, 1937), pp. 17–20; 4 figs.

ASSOCIATION DIVISION OF PALEONTOLOGY AND MINERALOGY

**Journal of Paleontology* (Tulsa, Oklahoma), Vol. 11, No. 8 (December, 1937)

"Distinctive Foraminifera of the Genus *Marginulina* from Middle Tertiary Beds of the Gulf Coast," by J. B. Garrett and A. D. Ellis, Jr.
"Blastoids of the Osage Group, Mississippian: Part II. The Genus *Cryptoblastus*," by L. M. Cline
"Stratigraphy and Fauna of the Sacajawea Formation, Mississippian, of Wyoming," by C. C. Branson
"Foraminifera of the Middle Tertiary Carapita Formation of Northeastern Venezuela," by H. D. Hedberg
"The Fusulinid, *Wedekindellina*, in Mid-Pennsylvanian Rocks of Kansas and Missouri," by Norman D. Newell and Raymond P. Keroher
"New Occurrence of the Upper Carboniferous Crinoid Genera *Amphicrinus* and *Synerocrinus*," by L. R. Laudon
"Genotype Designations and New Names for Invalid Homonyms among Paleozoic Gastropod Genera," by J. Brookes Knight

**Journal of Sedimentary Petrology* (Tulsa, Oklahoma), Vol. 7, No. 3 (December, 1937)

"The Diamond Head Black Ash," by Chester K. Wentworth
"Sedimentation of Colorado River in Runnels and Coleman Counties, Texas," by Raymond Sidwell and Clarence A. Cole
" 'Cave Pearls' in a Cave near Columbia, Missouri," by W. D. Keller
"The Use of Statistical Methods in Effecting Improvements on a Jones Sample Splitter," by George H. Otto

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 22, NO. 1 (JANUARY, 1938), PP. 116-123

THE ASSOCIATION ROUND TABLE

MEMBERSHIP APPLICATIONS APPROVED FOR PUBLICATION

The executive committee has approved for publication the names of the following candidates for membership in the Association. This does not constitute an election, but places the names before the membership at large. If any member has information bearing on the qualifications of these nominees, he should send it promptly to the Executive Committee, Box 979, Tulsa, Oklahoma. (Names of sponsors are placed beneath the name of each nominee.)

FOR ACTIVE MEMBERSHIP

Walter J. Achning, San Antonio, Tex.
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TWENTY-THIRD ANNUAL MEETING, NEW ORLEANS MARCH 16-18, 1938

CHAIRMEN OF COMMITTEES

General chairman, R. A. Steinmayer, Tulane University, New Orleans
Technical program, C. L. Moody, Ohio Oil Company, Shreveport

Finance, R. A. Steinmayer
Entertainment, Carroll E. Cook, 1403 Octavia Street, New Orleans
Reception, C. I. Alexander, Magnolia Petroleum Company, Lake Charles
Publicity, C. K. Moresi, Civil Court House, New Orleans
Hotels, J. Edward Lytle, 930 Main Street, Hattiesburg, Mississippi
Field Trips, Roy T. Hazzard, Gulf Refining Company, Shreveport
Transportation, Tatham R. Eskrigge, 1326 Harmony Street, New Orleans
Golf, Donald Goodwill, Jr., Department of Conservation, New Orleans

The twenty-third annual meeting of the Association will be held at the Roosevelt Hotel, New Orleans, Louisiana, March 16, 17 and 18, 1938. Members and friends planning to attend should notice that these dates are on Wednesday, Thursday, and Friday. On Tuesday, March 15, the several Association committees meet. On that day the general business committee holds its annual meeting, at which the officers and the district and division representatives arrange the business for presentation to the Association in annual meeting on Friday, the 18th. The executive committee of the Association also meets on Tuesday, the 15th, prior to the business committee meeting. Also the research committee, Donald C. Barton, chairman, has its round-table gathering on Tuesday evening, at which time the discussion will center on "The Time of Formation and Accumulation of Petroleum," a project proposed by F. M. Van Tuyl and Ben H. Parker, of the Colorado School of Mines.

The Society of Economic Paleontologists and Mineralogists will hold its twelfth annual meeting and the Society of Exploration Geophysicists will hold its ninth annual meeting concurrently with the Association meeting.

TECHNICAL PROGRAM

In addition to the list of titles appearing in the December issue of the *Bulletin* the following have been submitted as contributions to the New Orleans program.

C. E. MANION, "Bosco Oil Field"
G. S. BUCHANAN, "Cheneyville Oil Field, Rapides Parish, Louisiana, and Its Relation to the Areas of Mother Salt Deposition"
R. DANA RUSSELL, "A Test of Petrographic Correlation of Oil Sands in the Gulf Coast"
WILLIAM L. HORNER, "Sand Evaluation of Core Analysis"
ROBERT H. CUYLER and J. M. FROST, "The Geologic Aspect of Heaving Shales on the Texas Gulf Coast"
O. R. CHAMPION, "Subsurface Cross Section of the Cretaceous of South Texas"
J. BOYD BEST, "The Lopez Field of Webb and Duval Counties, Texas"
HARVEY WHITAKER, "The Hoffman Field of Duval County, Texas"
ROBERT ROTH, "The Triassic Period in the United States"
R. L. DENHAM, "Means Pool, Andrews County, Texas"
CHALMER J. ROY, "Type Locality of the Citronelle Formation, Citronelle, Alabama"
ALEXANDER DEUSSEN and KENNETH DALE OWEN, "Schlumberger Interpretation of Gulf Coast Typical Section"
J. R. LOCKETT, "Structural Significance of the Cincinnati Arch"
CLARK MILLISON, "Subsurface Study of the North Flank of the Wichita Mountains, Oklahoma"

J. Brian Eby, "Relation of Petroleum Exploration and Discovery to the Petroleum Industry"
P. H. O'Bannon and Charis R. Miller, "Anahuac, Chambers County, Texas"
Ed. J. Hamner, "Amelia Field, Jefferson County, Texas"
J. C. Poole and Kenneth D. Owen, "Placedo Field, Victoria County, Texas"
Phil Martyn, "Refugio Field, Refugio County, Texas"
Michel T. Halbouty, "Effect of Tides, Winds, and Barometric Pressures on Gulf Coast Production"
J. C. Miller and W. E. Greenman, "Time of Accumulation of Oil, Manvel Field, Brazoria County, Texas"
Frank S. Miller, "Resumé of Problems Relating to Edgewater Encroachment in Oil Sands"
R. J. Schilthuis, "Connate Water"

Papers on recent and current developments are now in course of preparation by the following authors

A. H. Bell, "Illinois"
J. E. Hupp, "Rocky Mountain Area"
R. B. Grigsby, "South Louisiana"
H. K. Shearer, "North Louisiana and South Arkansas"
Stuart Mossom, "South Texas"
Basil B. Zavoico, "Russia"

Other producing areas will have program representation, but the contributors have not yet been definitely named.

The United States Geological Survey, through J. B. Reeside, Jr., and Lloyd W. Stephenson, is contributing an important correlation paper in which the relationship of the Rocky Mountain and Gulf Coast Cretaceous will be pointed out. C. W. Cooke and W. H. Monroe of the Survey are coöperating with A. C. Munyan and H. N. Toler, respectively, in their papers. Samuel G. Lasky has finished a report on the Lower Cretaceous of New Mexico. The subject matter of this paper is of unusual present interest to workers in the Coastal Plain province.

Several papers dealing with Caribbean geology are in the prospective stage. The completed program will probably include some valuable contributions from this province.

Final titles and abstracts should be sent to C. L. Moody, Box 1129, Shreveport, Louisiana, before February 1. Printed programs will be prepared for use in New Orleans in which will appear author affiliations and abstracts of the papers to be delivered before the convention.

C. L. Moody

Shreveport, Louisiana
December 20, 1937

SEVENTEENTH INTERNATIONAL GEOLOGICAL CONGRESS, MOSCOW, JULY–AUGUST, 1937[1]

The Seventeenth International Geological Congress was held in Moscow and Leningrad, July 20-29, 1937. It had been 40 years since the Russian

[1] Report of an official delegate of the American Association of Petroleum Geologists and member of the Council of the Congress.

geologists were hosts to such a meeting and the Soviet scientists were eager to show their foreign colleagues what lengthy strides had been taken under their new socialistic regime. They made an impressive showing. Both in the arrangements provided for the general and technical sessions of the Congress, and especially in the numerous field trips to all parts of the Soviet Union, some of which preceded and others of which followed the meetings. The organization Committee seemed to have done a magnificent job. Loud and repeated praises were given the executive ability exhibited by Academician Ivan M. Goubkin, chairman, and Academician N. P. Gorbunov, secretary-general of the committee.

Approximately 400 foreign delegates, including about 80 Americans, were present for the Congress, the meetings of which were also attended by perhaps 600–700 Soviet geologists. General sessions were held in the auditorium of their exquisitely beautiful Conservatory of Music, and all remarks were simultaneously transmitted in six languages, Russian, English, French, German, Italian, and Spanish to head-phone sets at each seat. (An interesting fact, frequently commented upon, was that there were no German or Italian delegates present, the presumption being that passports had been denied by their own governments, not visas by the Soviet authorities. The Japanese geologists however, were well represented.)

Those facilities were not available in the smaller auditoriums in which the special technical sessions were held. There, for the most part, papers and discussions were given in Russian, English, or French, and usually summarized by interpreters into the two other languages not used by the speaker. These interpreters presumably did quite remarkable extemporaneous work with these abstracted translations, considering that regularly they were quite unfamiliar in either language with the technical subjects with which they were called upon to deal, and it occasioned much comment among the foreign delegates that these translations and interpretations had not been entrusted to Soviet geologists thoroughly acquainted with the technical problems under discussion, since the Soviet geologists seem to follow promptly and avidly all of the world literature dealing with their subjects and must number among their ranks many persons better qualified for such translating, at least on the Petroleum Excursion.

The first two floors of the conservatory had been given over to a Museum, presumably temporary, of rock and mineral specimens, maps, cross sections, and the like, which for care in selection and excellence in mounting exceeded anything the writer has ever seen. Some very beautiful tables and pedestals of matched woods in modernistic style had been constructed for the display of the specimens and evoked universal and enthusiastic commendation. This matter of laboratories or "museums" deserves special comment. Not only in Moscow, the capital, but also in Leningrad, where most of their scientific bodies are located, in Sverdlovsk, a provincial capital in the Urals which is the center of a mining district, at Rostov, which is not closely connected with any important mining or oil producing operations, at Baku in the center of the principal oil fields and at Tiflis in the heart of the Caucasus, but also in oil field camps and even at the locations for isolated wildcat test wells, the assemblages of rock, mineral and fossil forms, geological and geophysical maps, diagrams and cross sections, were of the very greatest benefit and interest to the visitors, particularly to the Americans and British, because in

nearly every instance legends and descriptions were given both in Russian and English. The tremendous amount of work done by the Soviet geologists in preparation for the meetings of the Congress, and particularly for the numerous field excursions, impressed everyone.

The Council of the Congress, charged with the business affairs and policies of the organization, met nearly every day. It consisted of eight official delegates. At its first meeting it approved the adoption of Russian as one of the "official" languages of the Congress, but for this meeting only. At its final meeting it recommended holding the next (1940) meeting in London, which was voted by the Congress as a whole, after a most urgent invitation had been extended by Japan.

There were few technical papers presented in the four general sessions of the Congress. The outstanding one was the inaugural address by Academician I. M. Goubkin, chairman of the Organization Committee and president of the Congress, on "The Oil Reserves of the World." No discussion took place on the papers presented at the general sessions, although a great deal of most interesting discussion usually followed the presentation of papers in the group meetings, at least in the Petroleum Section's four meetings, the only ones attended by the writer. So much of value can be gained by the exchange of ideas developed in such discussions that, as has always been advocated by the writer, it is a pity that the number of papers presented had not been reduced to permit more extended discussion of the more important ones.

The programs for all technical sessions were well filled, as an enormous number of papers had been submitted. Most of them had arrived sufficiently in advance of the meeting to allow the preparation of printed and bound volumes of adequate abstracts translated into the principal languages which were ready for distribution at the opening session.

Another evidence of the intelligent effort and energy so notably displayed by the Organization Committee was its preparation of guide books for the numerous optional field trips which preceded and followed the Congress. These likewise were translated into the principal languages, printed, bound, and profusely illustrated. They proved most valuable to the visiting delegates and aided in a ready understanding of the geological features visited, some of which exhibited extremely complicated conditions. A further gift to all delegates (and also to all registrants who proved unable to attend the Congress) was a new areal map of the entire Soviet Union in eight large sections.

The technical sessions were not too lengthy or too numerous to prevent various and most enjoyable social functions and frequent sight-seeing tours, not only in Moscow and Leningrad, but also in the principal cities visited on the field trips. In Moscow the Congress opened with a beautiful reception given by the Organization Committee and closed with an exquisite banquet in the Kremlin tendered by the government and attended by many of its highest officials. A most enjoyable affair was arranged for members of the Council by the Society for the Promotion of Cultural Relations with Foreigners. And an elaborate banquet was tendered all the delegates by the Leningrad Scientific Society at the Pushkin Palace near Leningrad.

The Petroleum Excursion was particularly pleasing to the writer. A special train of five compartment cars, one diner and one service car for the staff, carried 37 visiting geologists and 19 Soviet geologists over a route of

5,000–6,000 miles with a nice adherence to schedules, although the running time of the train was remarkably slow. The train would be put on convenient sidings where a fleet of automobiles or busses would meet it to make the trips to oil fields, outcrops, seepages and other points to be visited. A most agreeable non-geological business manager was in charge of the tour and his arrangements were greatly appreciated. A physician also accompanied the tour.

Brief visits were made to the newer Permian producing areas between the Volga River and the Ural Mountains. A very crowded week was spent at Baku visiting the important fields in the Apsheron Peninsula and another 2 weeks in other interesting parts of the Caucasus. Each day's trip had its special leader and the precise route, stopping points, maps and cross sections for explanations had been worked out most carefully and successfully. The visitors were impressed by the apparently universal ability of the Soviet geologists to make clear and concise statements, even through interpreters quite unfamiliar with the technical subjects, on very complicated geological conditions.

For the most part discussion was encouraged and usually questions were answered promptly and fully if they bore upon purely geological subjects. Some disappointment was expressed that more explanations were not given of their current geophysical methods of exploration for the visitors especially interested in that phase. Likewise statistic and economic matters were not well covered and little attention was given to the problems of petroleum technology with which also many geologists in other countries have to concern themselves. It is possible that in the Soviet Union this work is highly specialized and that the men most familiar with these allied subjects were not present on this excursion.

On the whole the Soviet geologists with whom the delegates came in contact impressed the visitors as keen, alert, friendly, hospitable and generous people. Any international congress held during a period when foreign relations are strained—to say the least—can be rather difficult but the Soviet geologists acquitted themselves most creditably. Their ardor for their form of government, their belief that it is superior to any other political scheme and their conviction that geology and all other sciences are better fostered under their regime than any other political form, cropped out on occasions, but under the circumstances propaganda was not too insistent.

On the platform in the auditorium where the general sessions were held huge banners displayed the following quotation, attributed to Stalin, translated into four different languages:

> Science is called Science just because it does not recognize fetishes and does not fear to raise its hand against everything that is obsolete and dying, and attentively listens to the voice of experience and practice.

J. Elmer Thomas

Houston, Texas
November, 1937

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BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 22, NO. 1 (JANUARY, 1938), PP. 124-128

AT HOME AND ABROAD

CURRENT NEWS AND PERSONAL ITEMS OF THE PROFESSION

At a meeting of the Tulsa Geological Society, Monday, December 6, 1937, C. L. Moody presented a paper, "Recent Oil and Gas Developments in Shreveport Area, particularly at Cotton Valley."

The Rocky Mountain Association of Petroleum Geologists held a meeting in Denver on November 15 at which time John G. Bartram presented a paper, "Shall We Simplify the Nomenclature of the Upper Cretaceous in the Rocky Mountains?" At the meeting held at Boulder, Colorado, December 6, John Clark spoke on "Stratigraphy of Tertiary Formations in the Rocky Mountain Area."

Mr. and Mrs. Norval Ballard, 1105 East Twentieth Street, Oklahoma City, announce the birth of a son, Charles Norval, at St. Anthony's hospital on November 15, 1937.

Allen Williams is now associated with the Turman Oil Company, a subsidiary of the Middle States Petroleum Corporation, as divisional geologist in the Houston division office of this company.

Arthur J. Tieje, professor of geology at the University of Southern California, Los Angeles, has returned from Australia. While there, he spoke before the Royal Societies of Sydney and Melbourne on the oil problems of California. He also studied the Permian section, and made extensive collections of Tertiary foraminifera. He will sail for Hongkong, Sumatra, Rangoon, and Calcutta on February 8, and spend some months in India, examining the Permian section, and adding to his fossil collections, especially foraminifera. In August he will sail from Bombay for New York via Persia, Egypt, and Gibraltar.

New officers of the Dallas Petroleum Geologists for the year 1938 are: president, Dilworth S. Hager, 932 Liberty Building; vice-president, R. E. Rettger, Sun Oil Company; secretary-treasurer, W. W. Clawson, Magnolia Petroleum Company.

E. L. Fipps is assistant district geologist for the Plymouth Oil Company in Texon, Texas.

Russell V. Johnson, consulting geologist, 913 Lancaster Building, Calgary, Alberta, was in southern Texas and Mexico during December.

At the Fort Worth Geological Society, November 17, 1937, Ronald K. DeFord of the Argo Petroleum Company, Midland, Texas, gave a report of the Seventeenth International Geological Congress held in Moscow the past summer.

The second annual meeting of the Carolina Geological Society was held on November 6 and 7 with 24 members and 16 visitors in attendance. The

meeting was held jointly at the University of North Carolina, Chapel Hill, and at Duke University, Durham, North Carolina. The following are the officers for the coming year: president, W. W. STRALEY, III, University of North Carolina, Chapel Hill; vice-president, W. C. BURGESS, Tennessee Mineral Production Company, Spruce Pine, North Carolina; secretary-treasurer, WILLARD BERRY, Duke University, Durham, North Carolina.

The retirement is announced of RUDOLF RUEDEMANN, New York State paleontologist. He was appointed assistant paleontologist in 1899 and has been State paleontologist since 1926.

LESLIE A. JOHNSON has joined the geological staff of the Sunray Oil Company, Tulsa. He received his B.S. from the University of Tulsa in 1931 and was formerly with Sinclair Prairie Oil Company.

W. A. J. M. VAN WATERSCHOOT VAN DER GRACHT has been elected a foreign fellow by the Geological Society of London.

WALLACE LEE has completed his report on the Mississippian rocks of Kansas, conducted coöperatively by the United States Geological Survey and the State Geological Survey, and has returned to Kansas for further studies of the subsurface geology.

A limited number of post-doctorate fellowships in the natural sciences (physics, astronomy, mathematics, chemistry, geology, agriculture, forestry, anthropology, and psychology) will be available through the National Research Council for the academic year 1938–1939. These fellowships carry stipends from $1,600 upward, and are open to citizens of the United States or Canada under the age of 35 years, for study in the United States or, under special conditions, in Europe. Applications for appointment to these fellowships should be filed with the secretary of the National Research Fellowships Board in the Natural Sciences, National Research Council, 2101 Constitution Avenue, Washington, D. C., on or before February 1, 1938.

O. F. VAN BEVEREN, formerly of Hollywood, California, may be addressed at N. V. Nederlandsche Pacific Petroleum Mij., Kebon Sirih No. 52, Batavia-Centrum, Java, D.E.I.

LINN M. FARISH has changed his address from Amiranian Oil Company, 39 Broadway, New York City, to Box 354, Ardmore, Oklahoma.

M. H. JAMESON of the Seismograph Service Corporation, Tulsa, Oklahoma, is located at San Fernando, Trinidad, British West Indies.

DON O. CHAPELL, geologist with the Transwestern Oil Company, and formerly located at Oklahoma City, is now at 1209 Atlas Life Building, Tulsa, where the company has moved its Oklahoma division office.

C. W. SANDERS, JR., has moved from Los Angeles to Houston, Texas, and may be addressed in care of the geological department, Shell Petroleum Corporation, Box 2099. His home address is 2108 Danville Street, Houston.

OLIVER B. KNIGHT has changed his address from Huasteca Petroleum Company, Mexico, D. F., to Standard Oil Company of Venezuela, Caripito, Venezuela.

R. W. McCanne, formerly with the Rocky Mountain Gas Company, Rawlins, Wyoming, is now with The Ohio Oil Company, Casper.

John A. McCutchin, district exploitation engineer for the Shell Petroleum Corporation in the Texas Panhandle, resigned December 1 to accept a position with the British American Oil Company in Tulsa, Oklahoma.

Luther H. White, manager of the land geological department for the Deep Rock Oil Company, has accepted chairmanship of the exploration committee of the International Petroleum Exposition which is to be held in Tulsa, May 14-21, 1938. Other members of the committee are: L. F. McCollum, vice-president in charge of exploration, Carter Oil Company, Tulsa; James H. Gardner, president, Gardner Petroleum Company, Tulsa; W. B. Wilson, district geologist, Gulf Oil Corporation, Tulsa; Frederic A. Bush, chief geologist, Sinclair-Prairie Oil Company, Tulsa; Ira H. Cram, district geologist, The Pure Oil Company, Tulsa; Dollie Radler Hall, administrative geologist, Amerada Petroleum Corporation, Tulsa; R. S. McFarland, vice-president and general manager, Seaboard Oil Company, Dallas; H. B. Fuqua, division geologist, Gulf Oil Corporation, Fort Worth; L. P. Garrett, vice-president in charge of land and geology, Gulf Oil Corporation, Houston; H. H. Nowlan, manager of land and geological departments, Darby Oil Company, San Antonio; W. B. Heroy, directing geologist in charge of foreign explorations, Consolidated Oil Company of California, New York; C. L. Moody, district geologist, Ohio Oil Company, Shreveport; Clark Gester, vice-president in charge of exploration, Standard Oil Company of California, San Francisco; C. R. McCollom, consulting geologist, Los Angeles; M. G. Cheney, president, Anzac Oil Company, Coleman; John G. Bartram, division geologist, Stanolind Oil and Gas Company, Casper; J. D. Thompson, Jr., Consulting geologist, Amarillo; O. C. Harper, Harper and York, Inc., Midland; Max W. Ball, consulting geologist, Denver; Marvin Lee, consulting geologist, Wichita; Charles J. Hares, district geologist, Ohio Oil Company, Marshall, Illinois; Curt de Cousser, Vacuum Oil Company, Lansing, Michigan.

At a meeting of the Tulsa Geological Society, December 20, D. W. Ohern, consulting geologist of Oklahoma City, presented a paper, "Geology of Some Canyons of the West: Grand, Zion, and Bryce."

On December 10, H. H. Bradfield of The Texas Company gave an illustrated discussion of "Pennsylvanian Ostracodes" before Fort Worth paleontologists.

At a meeting of the Rocky Mountain Association of Petroleum Geologists, Denver, Colorado, on December 20, Ralph Hubman spoke on "Notes on the Stratigraphy of the Maracaibo Basin, Venezuela."

N. J. M. Taverne, geologist with Shell Petroleum Corporation, has gone to The Hague from Houston, Texas, and may be addressed at 30 Carel van Bylandtlaan, G. A.

J. Edward Lytle, geologist with the Union Producing Company, may be addressed at 5520 Loyola Street, New Orleans, Louisiana.

Nelson B. Potter, formerly with the Mid-Continent Petroleum Corporation, Holdenville, Oklahoma, is now with the Cities Service Oil Company's geological department, Bartlesville Oklahoma.

PARKER A. ROBERTSON is with the Gulf Exploration Company, 3 London Wall Building, London, E. C. 2, England.

FRED BRASTED, JR., formerly with the Stanolind Oil and Gas Company, Tyler, Texas, is now in the land department of the Phillips Petroleum Company at Midland, Texas.

C. P. COLLINS has been transferred from the position of manager of the northern division of the Eastman Oil Well Survey Company to the position of assistant general manager of the same company. His address is 4909 Fannin Street, Houston, Texas.

CLEMENTE GONZALEZ DE JUANA has resigned his position as district manager of the Compañia Española de Petroleos to become consulting geologist for the Ministerio de Obras Publicas of Venezuela. His address is Apartado 1253, Caracas, Venezuela.

DON B. GOULD spoke before the Rocky Mountain Association of Petroleum Geologists at Denver, Colorado, January 3, 1938, on the subject "Structure and Stratigraphy between Trout Creek Pass and the Buffalo Parks, South Park, Colorado."

New officers of the Rocky Mountain Association of Petroleum Geologists, Denver, Colorado, are: president, CHARLES S. LAVINGTON, Continental Oil Company; first vice-president, WARREN O. THOMPSON, of Boulder; second vice-president, DAVID B. MILLER; secretary-treasurer, NINETTA DAVIS, 224 U. S. Customs Building.

FREDERIC A. BUSH delivered his presidential address before the Tulsa Geological Society, January 3, "Geology of the Moore Field."

Officers of the Tulsa Geological Society for the new year are: president, ROBERT J. RIGGS, Stanolind Oil and Gas Company; first vice-president, N. W. BASS, U. S. Geological Survey; second vice-president, CLARK MILLISON, McBirney Building; secretary-treasurer, L. A. JOHNSON, Sunray Oil Company; editor, R. V. HOLLINGSWORTH, Shell Petroleum Corporation.

Newly elected officers of the Geological Society of America are: president, ARTHUR L. DAY, director of the Geophysical Laboratory, Washington, D. C.; vice-presidents, WAYLAND T. VAUGHAN, formerly director of the Scripps Institution of Oceanography, University of California, WARREN J. MEAD, Massachusetts Institute of Technology, JOSEPH A. CUSHMAN, Sharon, Massachusetts, NORMAN L. BOWEN, University of Chicago; secretary, CHARLES P. BERKEY (re-elected), Columbia University; treasurer, EDWARD B. MATHEWS (re-elected), Johns Hopkins University.

The Paleontological Society, an affiliate of the Geological Society of America, elected the following officers: president, C. W. GILMORE, U. S. National Museum, Washington, D. C.; vice-president, GAYLE SCOTT, Texas Christian University, Fort Worth, Texas; secretary, B. F. HOWELL (re-elected), Princeton University, Princeton, New Jersey; treasurer, R. R. SCHROCK, Massachusetts Institute of Technology, Cambridge, Massachusetts.

The Society of Economic Geologists elected, a year in advance, its president for 1939, ARTHUR C. VEATCH, of New York City. DONALD H. MCLAUGHLIN, Harvard University, is president during 1938.

WILLIAM KRUM may be addressed in care of Petty Seismic Party, Caribbean Petroleum Company, Apartado 19, Maracaibo, Venezuela.

The Appalachian Geological Society, Charleston, West Virginia, has elected new officers as follows: president, ROBERT C. LAFFERTY, Owens, Libbey-Owens Gas Department, Charleston; vice-president, J. HAWKER NEWLON, Philadelphia Gas Company, Pittsburgh; secretary-treasurer, CHARLES BREWER, JR. (re-elected), Godfrey L. Cabot, Inc., Charleston.

The Fort Worth Geological Society new officers are: president, A. L. AKERS, Stanolind Oil and Gas Company; vice-president, C. E. HYDE, 1715 W. T. Waggoner Building; secretary-treasurer, H. H. BRADFIELD, The Texas Company.

The Western Kentucky Geological Society was recently organized at Owensboro, Kentucky, with the following officers: president, JAMES POTEET, Kentucky Natural Gas Company; vice-president, N. W. SHIARELLA, of Miller and Shiarella; secretary-treasurer, RALPH KNIPE, Ohio Oil Company. Members of the society's executive committee are W. KEITH MILLER, Carter Oil Company and GEORGE R. WESLEY, of Snowden and McSweeney Company and Cumberland Petroleum Company. The society has thirty members.

R. J. SCHILTHUIS, petroleum engineer of the Humble Oil and Refining Company, recently spoke before the Houston Geological Society on "Connate Waters in Oil and Gas Sands."

R. A. SMITH, State geologist of Michigan, recently led a discussion on "The Origin and Accumulation of Petroleum in Michigan," before the Michigan Geological Society at Bridgeport.

R. M. BEATTY, formerly district geologist with the Tide Water Associated Oil Company at Corpus Christi, Texas, is now with the Trinity Oil Company.

C. I. ALEXANDER, district geologist for the Magnolia Petroleum Company, presented "A North-South Cross Section of the Louisiana Gulf Coast," at a meeting of the South Louisiana Geological Society, Lake Charles, Louisiana, December 20.

The Oklahoma City Geological Society has elected new officers as follows: president, E. A. PASCHAL, Coline Oil Company; vice-president, DAN O. HOWARD, Oklahoma Corporation Commission; secretary-treasurer, R. B. CURRY, Carter Oil Company.

The new officers for the Kansas Geological Society, Wichita, Kansas, are: president, EDWARD O. KOESTER, Darby Petroleum Corporation; vice-president, GLENN C. WOOLLEY, Transwestern Oil Company; secretary-treasurer, FORREST E. WIMBISH, 517 North Chatauqua.

The 148th meeting of the American Institute of Mining and Metallurgical Engineers will be held in New York City, February 14–17, 1938. The technical program will be presented in the Engineering Societies Building, 29 West 39th, and the dinner-smoker, dance, and banquet will be held at the Waldorf-Astoria Hotel, 50th Street and Park Avenue.

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224 U. S. Customs Building

Dinner meetings, first and third Mondays of each month, 6:15 P.M., Auditorium Hotel.

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Secretary-Treasurer - - Forrest E. Wimbish
517 North Chautauqua

Regular Meetings: 7:30 P.M., Allis Hotel, first Tuesday of each month. Visitors cordially welcomed.

The Society sponsors the Kansas Well Log Bureau which is located at 412 Union National Bank Building.

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Meets the first Friday of every month, Civil Courts Room, Caddo Parish Court House. Luncheon every Friday noon, Caddo Hotel.

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Shell Petroleum Corporation

Meetings: First Monday at noon (12:00) and third Monday at 7:00 P.M. at Majestic Hotel. Visiting geologists are welcome to all meetings.

OKLAHOMA

ARDMORE GEOLOGICAL SOCIETY
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Phillips Petroleum Company

Meetings: First Tuesday of each month, from October to May, inclusive, at 7:30 P.M., Dornick Hills Country Club.

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Oklahoma Corporation Commission
Secretary-Treasurer - - - - R. B. Curry
Carter Oil Company, 420 Colcord Building

Meetings: Second Monday, each month, 8:00 P.M., Magnolia Building. Luncheons: Every Monday, 12:15 P.M., Black Hotel.

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Meetings: First and third Mondays, each month, from October to May, inclusive, at 8:00 P.M., fourth floor, Tulsa Building. Luncheons: Every Thursday, fourth floor, Tulsa Building.

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Meetings: Regular luncheons, first Monday of each month, 12:15 noon, Petroleum Club. Special night meetings by announcement.

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Meetings: Monthly and by call.

Luncheons: Every Friday, Cameron's Cafeteria.

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Meetings: Luncheon at noon, Worth Hotel, every Monday. Special meetings called by executive committee. Visiting geologists are welcome to all meetings.

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Skelly Oil Company

Regular meetings, every Thursday at noon (12:15) at the Houston Club. Frequent special meetings called by the executive committee. For any particulars pertaining to meetings call the secretary.

TEXAS

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Meetings: Third Friday of each month at 8 P.M. at the Petroleum Club. Luncheons every Monday noon at Petroleum Club, Alamo National Building, San Antonio, and at Plaza Hotel, Corpus Christi.

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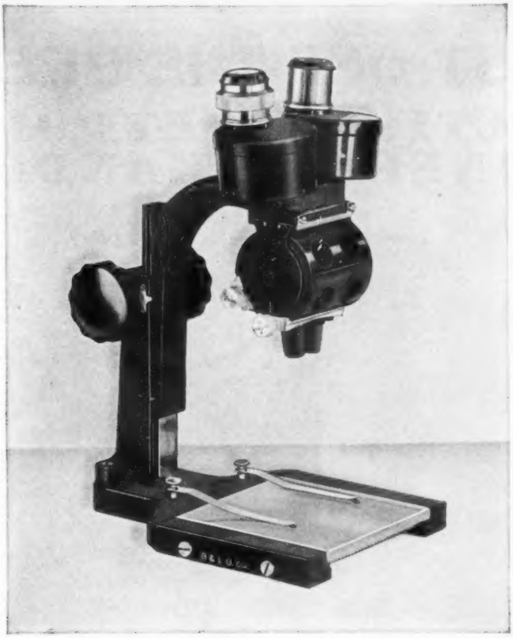
Godfrey L. Cabot, Inc., Box 348

Meetings: Second Monday, each month, at 6:30 P.M., Ruffner Hotel.

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